A
COMPLETE TREATISE
OF
MINES:

Extracted from
The MEMOIRES d'ARTILLERIE.

To which is prefixed, by Way of INTRODUCTION,

Profeſſor BELIDOR's DISSERTATION on
the FORCE and PHYSICAL EFFECTS of
GUNPOWDER.

Illuſtrated by a great Variety of COPPER-PLATES.

By HENRY MANNINGHAM.

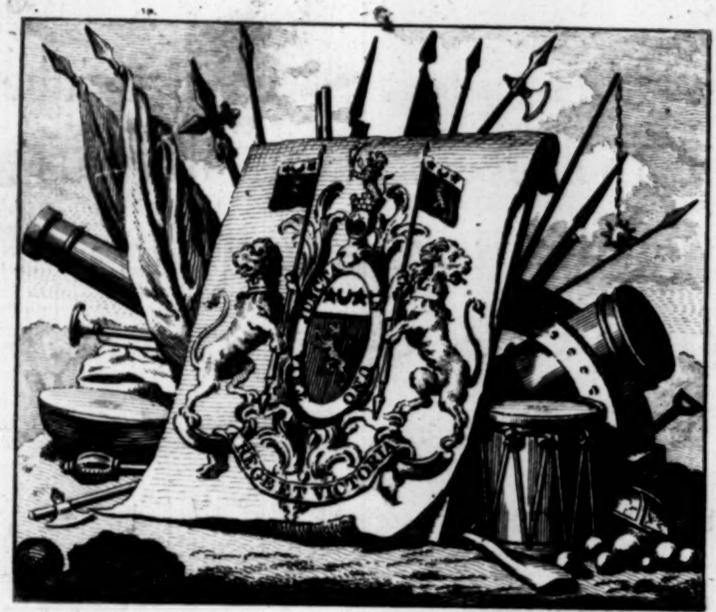
K

Quis reprehendet noſtrum Otium, qui in eo non modo
noſmetipſos hebeſcere et languere nolumus, ſed etiam,
ut plurimis proſimus, nitimur?
CICERO.

LONDON:
Printed for A. MILLAR, in the *Strand.*
MDCCLVI.

45.
12. 17.
873

BRITISH MUSEUM



C. Grignion sculp.

TO THE RIGHT HONORABLE
Sir JOHN LIGONIER,
GENERAL of HORSE,
LIEUTENANT-GENERAL of the ORDNANCE,
GOVERNOR of PLYMOUTH,
COLONEL of the Royal Regiment of HORSE GUARDS BLUE,
ONE of HIS MAJESTY's moſt Honorable PRIVY COUNCIL,
AND
Knight of the Noble Order of the BATH.

SIR!

THE PROTECTION of Arts and Sciences, has ever been eſteemed the Province of the Great and Illuſtrious: And tho' there is nothing in the whole Circle of polite and uſeful Literature, that might not juſtly claim your Patronage; yet, no one Part is more peculiarly intitled to it, than the Subject of the following Sheets.

For to whom can a Treatiſe, relative to any Branch of the Art of War, be ſo properly inſcribed as to you, Sir, whoſe profound Knowlege and conſummate Experience in every Part of War, are ſo univerſally confeſſed, and ſo juſtly admired by Thoſe, who make that extenſive Art their favorite Study?

Nor can I, on this Occaſion, deny myſelf the Pleaſure of obſerving, That I eſteem it a very ſingular Felicity, that I am permitted the Honor of prefixing Your Great Name to the ſubſequent Treatiſe on Mines. A Liberty of this

Kind, on any other Principle, had been, doubtleſs, in me, an Inſtance of the higheſt Preſumption: But, being now happy in the Acquiſition, I may venture to promiſe myſelf, under the Luſtre of your Patronage, not only that the Work itſelf may be preſerved from Oblivion; but, likewiſe, that it may invite others to cultivate an Acquaintance with that Branch of Knowlege, which is of equal Uſe and Importance in the Art of War.

I HAVE only, SIR, farther, to beg Your Indulgence, while I take the Liberty to renew my humble Acknowlegements, as well for every previous Honor, wherein either myſelf, or my poor Indeavors, may have ſhared Your generous Countenance; as, now, again, more eſpecially, for that ſingular Condeſcenſion, by which You are pleaſed to allow me the preſent Opportunity of teſtifying in this public Manner, that profound Gratitude, Reſpect and Duty, with which I am,

SIR,

Your moſt obedient,

And moſt obliged

Humble Servant,

HENRY MANNINGHAM.

St. James's,
October 20th, 1756.

THE TRANSLATOR's

PREFACE.

WERE I to enter into a minute Inquiry concerning the ORIGIN, and ANTIQUITY of Mines, the vaſt Advantage the Antients reaped from them, together with the Analogy between the earlieſt and lateſt Methods of Practice, it might eaſily be made to appear, That the Manner in which the Antients wrought their Mines, nearly correſponds with that practiſed by our modern Engineers; but this is not my preſent Deſign: as I ſhall reſerve the Diſcuſſion of that Point, together with ſome very intereſting Particulars, for the Subject of another Treatiſe, ſhortly to be publiſhed.

THE SCIENCE of Mines is at preſent become a principal Branch in the Attack, but eſpecially ſuch in the Defence of Places; as ſhall be particularly ſhewn in my next Treatiſe: I will therefore, at this time, only mention a word or two, in reference to the Motive, which incouraged me to the preſent Work; and what I have to requeſt at the Hands of the Reader.

RESPECTING the firſt of theſe Particulars, I would obſerve, That the celebrated Treatiſe, intitled *Memoires d'Artillerie*, having met with univerſal Applauſe from all *the Literati*; I flattered myſelf, that a Tranſlation of

THE EXTRACT here taken from that Piece, (long ſince eſteemed by an able and experienced Engineer of our own, the very beſt Performance in the whole *Memoires*) would be no unacceptable Preſent to the Public; eſpecially as it comes here attended with ſome other valuable Pieces, that bear a ſtrict Connection with the main Argument.

FOR, as there is now a Demand for a ſecond Edition of this Tract, I have made it my Buſineſs, not only to correct it from ſuch Inaccuracies, as might have eſcaped my notice in the former Publication; but, to render it ſtill more entertaining and uſeful, have given it this ſingular Advantage: That it brings into View with it thoſe excellent Diſſertations of the famous Marſhal *de Valliere* and Profeſſor *Belidor*,

Belidor, as Matters of real Conſequence to the important Subject under conſideration.

As to the Piece written by the former of theſe Gentlemen, [Marſhal *de Valliere*] I cannot deny myſelf the Pleaſure of quoting a Paſſage of the late ingenious MR. ROBINS, in his Preface to his admirable Treatiſe on GUNNERY, in which he beſtows no ſmall Encomiums on this Piece of the Marſhal; his Words are theſe: "For, "ſays he, before I leave this Head "[*h. e.* The Advantage of MINES] I "cannot but in juſtice mention the "great Improvement of the Doctrine "of MINES, which is contained in "that excellent Diſſertation of the "Marſhal *de Valliere*, annexed to the "third Volume of the *French Poly-* "*bius.*

“ *bius.** For nothing can be more “ complete, than the Manner in “ which the different Stages of Mines “ are there diſtributed: Indeed, the “ Form there aſſigned to the Excava- “ tion, cannot be rigorouſly, what the “ Author ſeems to ſuppoſe; but this “ Exception has nothing to do with “ his general Rangement of the “ Chambers, which is extremely well “ contrived for the huſbanding of the “ Ground, and the annoying of the “ Enemy.” Thus far Mr. *Robins.*

In truth, all thoſe Authors, who have treated on this Subject, ſuch, for Inſtance, as Profeſſor *Belidor*, L’Abbé *Dedier*, Monſ. *le Blond*, Monſ. *Dulacq*, *&c.*

---

* The Reader is deſired to obſerve, that this Gentleman’s Diſſertation here ſo deſervedly admired, is greatly augmented and improved by Notes in the following Treatiſe.

&c. have agreed in their Teſtimonies to this Piece; jointly confeſſing the ſingular Services he has done the Public by his happy Illuſtrations on this abſtruſe Branch of engineering; ſince, in agreement with Mr. *Robins*'s Obſervation above, by his great Sagacity and Experience, he appears to have been the firſt, who hath inſtructed us in that moſt excellent Diſpoſition of *the Fourneaux*, which at preſent univerſally obtains; and which, as a neceſſary Conſequence, almoſt gives us room to ſay, That the Art of MINING is now, at laſt, PERFECTED.

NOW, as to the Piece written by the latter of theſe Gentlemen [Monſ. *Belidor*] which treats on the Force and phyſical Effects of Gun-Powder, the Profeſſor himſelf will make my Apology for giving it a Place on this Occaſion; ſince he very judiciouſly obſerves, That there are ſeveral Things connected with the Theory of MINES, which admit of no Explication, unleſs Gun-Powder be made part of the Queſtion.

AND now, for what concerns the other Particular mentioned above, deſigned as a cloſe to this Preface: The Favor, which I have to requeſt of thoſe, who may give themſelves the trouble of peruſing the following Sheets, is no other than a candid INDULGENCE to what has been here attempted. Nor can I allow myſelf to doubt, but that, as an ingenious Writer very juſtly remarks, they will ſeverally conſider: "That a Tranſlator is only a Laborer in another Man's Vineyard. That an

Author can command his Thoughts and Expreſſions, and can vary both as he pleaſes: But he who tranſlates has no ſuch Privilege; he is confined to his Author's Thoughts, and is, conſequently, under an indiſpenſible Obligation to render his Meaning in an happy, eaſy, and natural Manner." This has been my Aim; how far I may have ſucceded is intirely ſubmitted to the Determination of the judicious and candid READERS, by their obedient Servant,

THE TRANSLATOR.

TABLE OF CONTENTS.

Page

INTRODUCTION. 1

Of Mines. 47

Memoir of an Engineer on Mines. 49

Manner of conſtructing Mines, Fourneaus, Saps, Galleries, &c. *by an Engineer and Artillery Officer.* 54

Table for charging Mines by Marſhal Vauban. 70

General Rules to charge Mines, and Fourneaus properly. 71

Page

Of the Countermines of the Beſieged to annoy the Enemy. 75

Miners Tools. 80

Memoir on Mines, by Mr. de la Motte, *chief Commiſſary.* 86

Of the Fruſtum of a Cone with reſpect to the Aperture of Mines. 99

Proportion of the Galleries, and Branches. 103

Of the different ſorts of Mines. 104

Of the Diſtance of the Galleries. 105

Of the Diſpoſition of the Fires. 113

Mr. de Valliere's *Diſſertation on Mines, and their Advantages in the Defence of Places.* 121

Page
Explanation of the Figure, and Diſpoſition, of Fourneaus. 139

Mr. de Valliere's *Table for the Charges of Mines.* 155

Mr. Belidor's *new Experiments to find the proper Charges for the Chambers of Mines.* 156

Soon will be publiſhed by the ſame Author,

ESSAYS

On a Variety of

MILITARY SUBJECTS.

AN ESSAY ON THE THEORY OF GUNPOWDER.

INTRODUCTION.

AS Gunpowder is now become the very Eſſence of Artillery, and is undoubtedly of moſt extenſive Uſe, it is ſurprizing to obſerve, that Perſons, otherwiſe Curious, have been rather negligent in ſeeking into the phyſical Cauſes of its Effects, and have indeed, hitherto conſidered it as a Thing incomprehenſible: Nor ſo only, but it has, in ſhort, been looked upon as a ſort of Preſumption even to undertake the Inquiry. Suppoſing, however, that we ſhould not be ſo happy as to ſucceed in an Attempt of this Kind; it is, nevertheleſs ſufficient, that the Motive, which prompts our Reſearches, is conſiſtent with our Profeſſion, and that it is therefore ſuch as ought to plead our Excuſe with the Learned.

It is certain, we are now ſo greatly improved in Science, as to have it in our Power, to treat abſtracted Subjects with that Clearneſs and Demonſtration, which they were by no Means thought capable of in paſt Ages; but through how many Hands have they been obliged to paſs, before they could attain this deſired Perfection? Had the Effects of Gunpowder been inquired into from the Period, in which it was firſt obſerved to be of ſuch eminent Uſe, thoſe, who are at preſent inclined to examine this Point, might not only have reaped real Advantage on the Subject, but had ſome room to hope, that, from the Lights thus borrowed from their Predeceſſors, they themſelves might have yet made farther Advances: But to our great Mortification, this happens not to be the Caſe. For, except ſome Tracts, ſcattered in the Memoirs of the Academy of Sciences, which have, indeed, been ſerviceable to my Deſign; I have found nothing of any Conſequence. So that I am but little more than on a Level with thoſe, who are forced to draw the whole from their own Obſervations; for which Reaſon, I beg the ſame Candour, that Readers are generally diſpoſed to allow ſuch Undertakings.

GUNPOWDER was invented in the beginning of the 14th Century, by *Bartholde Schwartz*, formerly a Cordelier of *Fribourg*, who applied himſelf to Chemiſtry; and it is pretended, that it was by mere Accident, that he diſcovered ſo ſurpriſing a Phænomenon.

NOW, in ſuggeſting my Thoughts on this Subject, my Method will be this: I ſhall,

IN the firſt Place, obſerve, That the Effects of Gunpowder neceſſarily depend on the Properties of the Air. For Gunpowder in its original State, is no more than a Fire, which has the Power of putting the Air into Motion; becauſe this Effect being attained, it is Air alone, that produces the other Phænomena, as I ſhall hereafter demonſtrate.

SECONDLY, I ſhall ſpeak to the Qualities of the Materials, which enter its Compoſition: Namely, Saltpetre, Sulphur, and Charcoal; as the beſt Means of ſhewing their reſpective Action on each other, and the Neceſſity of their Mixture.

THIRDLY, I ſhall conſider the Manner of its taking Fire, and what Law it obſerves in this Caſe.

BUT before I proceed to examine each of theſe Subjects particularly; leſt they ſhould appear a little abſtruſe to thoſe, who are not deeply read in Phyſics; it will be proper to adviſe them, not to paſs over any one Article in a ſuperficial Manner, becauſe they will find each of them abſolutely eſſential to their becoming perfect Judges of this Memoir. To begin then with

THE Firſt of theſe Heads.—Now, as Air is avowedly ponderous, that which we breathe being preſſed by the Weight of the whole Atmoſphere, the Effort it makes to dilate itſelf ſhould be equal to that, which is uſed to compreſs

preſs or confine it; and the *Niſus* by which it attempts its Liberty or Expanſion reſulting intirely from that Elaſticity, which is inherent in itſelf, it may be ſaid, that the Air, which correſponds to the Earth's Surface, is, through its Elaſticity, in Equilibrio, with the Weight of the whole incumbent Atmoſphere.

If it be aſked, wherein the Elaſticity of the Air conſiſts; it cannot I apprehend, be conceived of more adequately, than in ſuppoſing it compoſed of an Infinity of ſmall Springs, which being preſſed by ſome Power, endeavour to free, and replace themſelves in their natural State: This gives them an elaſtic Force, which is in the Ratio of the compreſſing Force; or, which is the ſame, in the inverſe Ratio of the Decrement of the Space they occupied before Compreſſion. When I ſay, the Elaſticity of the Air is formed by an Infinity of ſmall Springs, I do not affirm it to be abſolutely thus; ſince we have no Idea of its Figure: We are only certain of the Exiſtence of this Elaſticity, becauſe it is an experienced Fact; and to fix the Idea, it may be conceived compoſed of an Infinity of ſmall Springs; and whenever it may be found intirely different, its Properties however will remain invariable.

Air has likewiſe the Power to rarify itſelf by Fire. For, as the Action of Heat conſiſts in a ſubtile Matter put into Motion, when this Matter inſinuates itſelf into a certain Quantity of Air, it expands the ſmall Springs, which then occupy a much larger Space than before, provided nothing obſtructs; but if they are reſtrained, and as it were confined by the Reſiſtance of any Powers, they will, from all Parts, endeavour to reſiſt theſe Powers, in order to diſperſe them. Now, the greater we ſuppoſe the Number of theſe Springs, which are thus compreſſed; ſo much greater will the elaſtic Force of the Air be, when put into Motion by Heat: It then follows from hence, that condenſed Air, attempting Rarefaction, becomes ſuſceptible of a much greater Degree of Elaſticity, than if it was in Equilibrio with that which we breathe; and that therefore the Degree of the Elaſticity of compreſſed Air, increaſes in the inverſe Ratio of the Decrement of its Space, tho' rarified with the ſame Degree of Heat.

Moisture likewiſe greatly augments the Air's elaſtic Force, whether it be condenſed or rarified; For, ſince Moiſture contracts the ſmall Springs, of which we ſuppoſe the Air to be compoſed; they of neceſſity preſs better upon each other, and therefore of courſe are capable of containing a greater Quantity of it, than was contained before, in the ſame Space. I ſhall not here detain the Reader by attempting a Detail of ſuch farther Reaſons concerning the Properties of the Air as may be more particular: Experience, which decides abſolutely, and which is conſonant to what we have ſaid, is the moſt convincing Proof in theſe Matters. But to form our Sentiments on the Effects of Rarefaction and Condenſation with ſuch an exactneſs, as may enable us to apply them to Gunpowder with greater Advantage; it is highly requiſite, that we be previouſly informed in what here follows.

If we ſuppoſe a hollow Sphere, of an inſenſenſible thickneſs, one Foot Diameter, replete with common Air, which cannot tranſpire through any Aperture; this Air, by means of its Elaſticity, will be in Equilibrio with the external Air: But as a Column of this external Air, whoſe Baſe is one Foot or 144 Inches, weighs about 2232 Pounds; if the Surface of this latter, *h. e.* the Sphere, was 144 Inches, it would ſuſtain the Preſſure of 2232 Pounds:

But the Sphere having a Foot Diameter, the Surface will be 452 Inches; therefore the confined Air will preſs the concave Surface with a Force equal to 7006 Pounds: For 144 Inches bears the ſame Proportion to the Surface of the Sphere, as 2232 Pounds bears to the Reſiſtance of the incloſed Air. If we conſider alſo a cubic Foot, hollow, containing a Quantity of Air equal to its Bulk, this being ſtill in Equilibrio with the incumbent Atmoſphere, each Side of a Foot Square will ſuſtain a Preſſure equal to 2232 Pounds; conſequently, the ſix together will ſuſtain a Weight of 13,392 Pounds, which is the whole Effort the incloſed Air will make to dilate itſelf.

In short, if we ſuppoſe a hollow Cylinder, every where perfectly ſtopped, the Diameter of whoſe Baſe is one Foot, and its Altitude, likewiſe, the ſame, the incloſed Air by reaſon of its Elaſticity, being always in Equilibrio, with the external Air; there will be the ſame Ratio of the Square of the Diameter of one Foot, to the Area of the Circle; as there is of 2232 Pounds, to the Reſiſtance of each Circle, which is found to be 1753: Thus then it appears, that, in the general, the elaſtic Force againſt the interior Surface of a Body, or one of its Parts, will be always found, by conſidering, that this Force is equal to the Weight of a Column of Air, whoſe Baſe is equal to the whole Surface, or one of its Parts, and whoſe Altitude is that of the Atmoſphere.

Let us again have recourſe to our Sphere of a Foot Diameter: If the Air confined in a Sphere of this Sort was rarified to ſuch a Degree as to fill a Space 4000 Times larger than its own, it's elaſtic Force would thereby become capable of a Reſiſtance 4000 Times greater, than when in Equilibrio with the Atmoſphere. Now, Rarefaction being the Cauſe of the elaſtic Force Air acquires, it follows, that this Force will be known, when the Rarefaction can be meaſured; I mean, when it can be known how much it exceeds that of the Air we breathe. But ſince we are here no farther concerned with Rarefaction than as it relates to Gunpowder alone, whoſe Force wholly conſiſts in its Power to rarify the Air wherewith it is mixed, as was before obſerved; it is therefore clear, that nothing more is wanting for our full Inſtruction in this Caſe, but only that we know to how great a Degree it is capable of being rarified: Nor are we here totally to ſeek, ſince according to Mr. *Amonton*'s Experiments, and thoſe of my own, a determinate Quantity of Gunpowder being inflamed, augments its Space 4000 Times, provided it have Opportunity of dilating the Air with which it is mixed: That is, for Inſtance, a cubic Foot of Gunpowder, being fired, diffuſes a Flame, whoſe Bulk poſſeſſes 4000 cubic Feet, and rather more. Now, fully to apprehend wherein this Rarefaction conſiſts, we are to take into the Account, not only the whole Air, which was confined in the Grains of Gunpowder; but, likewiſe, all that, which was found in the Interſtices between the Grains, put into Action by the Fire of the Sulphur and Charcoal, and by that Means intirely dilated: That is to ſay, theſe Particles are ſeparated from each other by the Motion of the ſubtile Matter, which may be here conſidered as the Fire itſelf; conſequently therefore, Gunpowder, fired, is no more than an elaſtic Fluid.

Now, if we ſuppoſe the Sphere of a Foot Diameter filled with Gunpowder, and that all this Powder could take Fire without breaking the Surface, the Conſequence muſt be, that it would take the Form of a Fluid, which would augment it's Bulk, meaning, that of the Sphere, 4000 Times, ſuppoſing it to have full Liberty to dilate itſelf; but, as it is evidently obſtructed by it's Poſition, it will no doubt make the ſame Reſiſtance on the Sphere with that juſt mentioned, the incloſed Air being here again ſuppoſed to be rarified 4000 Times, which is the ſame as ſaying, that it weighs 23332000 Pounds: For Gunpowder inflamed, will produce the ſame Effect as rarified Air, be the efficient Cauſe as it will, while each endeavours to dilate itſelf equally, for as much as their whole Power abſolutely conſiſts in that Action. From hence alſo we ſhall find, following only the above Principle, what is the Preſſure of Powder both in a Cube and a Cylinder. For having already ſeen, that in the Cube, for Example, natural Air reſiſted with a Force equal to 13,392 Pounds; when it comes to be filled with Gunpowder, its Reſiſtance is conſequently 4000 Times greater, which is to ſay, that it equals 53568000 Pounds. Hence it appears not impoſſible to reduce the Force of Gunpowder to Calculation, when the Quantity, and Figure of the Chamber, wherein it is confined, are known. But that, which may poſſibly, prevent the Calculation's being accurately true, is, that the Powder does not all take Fire at the ſame Inſtant, and that the reſiſting Bodies yield directly as the Powder begins to take Fire: In which Conſiderations, we have the real Cauſe, that a Cannon-Ball goes out of the Piece before all the Powder is fired, and that Shells and Grenades burſt immediately as one Part of their Charge takes Fire, the Charge being never totally conſumed when they burſt; as evidently appears by the Impreſſion, which ſuch Parts of theſe Bodies, whoſe Charges afterwards take Fire, are known to make, in the Places, where they reſpectively fall. Theſe Inconveniencies, however, might be prevented, could we once aſcertain in what Proportion Gunpowder takes Fire.

It muſt be obſerved notwithſtanding, that if the Air which we have ſuppoſed in the Sphere, Cube, and Cylinder, in rarifying itſelf, did, by its elaſtic Force, enlarge the Capacity of theſe Bodies, its Elaſticity would decreaſe in Proportion to the Increment of it's Space: For Inſtance, if the Air in the Sphere, being rarified to a certain Degree, had enlarged it to two Feet Diameter, it's Preſſure then would be only the eighth Part of what it had been capable of, ſuppoſing the Surface of the Sphere to have remained inflexible. In like Manner, if one of the Circles of the Cylinder was to ſeparate from its oppoſite, in ſuch a Ratio, that the Surface of the Cylinder, always accompanying this Circle, increaſed its Altitude proportionally as the Air rarified itſelf, except it ſhould find Means to eſcape; it's Elaſticity will be decreaſed in the Ratio of the Increment of the Cylinder's Altitude: So that if the Altitude of the Cylinder becomes double, each Circle will ſuſtain only half the Preſſure, which the rarified Air would have made, had it not been dilated at all. Now, ſince Gunpowder inflamed, is nothing more than Air rarified to a very great Degree; it is obſervable, that if, proportionally as it takes Fire, the Space, wherein it was confined, increaſes; the Force, it would have had, were it to be all inflamed before any Thing gave Way, will be diminiſhed in Proportion as it ſhall be found to dilate itſelf. In ſhort, it is moreover, to be obſerved, that if the Air, which is mixed with the Gunpowder in the Sphere of a Foot Diameter, or in a Body of any other Figure, was twice as denſe as it is in it's natural State, the Powder, rarifying itſelf, would have a double Force; and, on the contrary, were it twice as much expanded, it's Force would then be decreaſed by one half: Which ſhews that the ſame Quantity of Gunpowder ſhall have a greater or leſs Force, according as the Air it rarifies, happens to be more or leſs denſe. It is ſcarce credible, that Gunpowder is a Species of Barometer; and that by endeavouring to perfect this Machine, the Properties of the Air were diſcovered, without the Knowledge of which it had been impoſſible to argue juſtly on the Effects of Gunpowder.

PHILOSOPHERS univerſally admit the great Effects, which the Air is capable of, when, under a State of Confinement, it becomes rarified to a certain Degree; but as this Reaſoning will not afford ſufficient Conviction to many other People, who cannot apprehend it's Power for producing ſuch prodigious Effects; I would here deſire them to conſider, that the major Part of thoſe aſtoniſhing Things, which happen in Nature, are ſolely the Operations of Air. Thoſe ſmall Iſlands, for Example, which on a ſudden appeared in the *Archipelago*, near that of *Santorini*, ſprang up from the Boſom of the Earth, above the Surface of the Sea, where it was upwards of ſixty Fathom deep, from no other Cauſe, but that the ſubterraneous Fires had rarified the Air confined in the Viſcera of the Earth forming thoſe Iſlands: So that theſe Species of Mines, which are greatly ſuperior to ſuch as are ſprung by

Means of Gunpowder, muſt have acted with prodigious Force, to raiſe ſuch vaſt Bodies; ſince, independent of their immenſe Weight, they had alſo the Water and Atmoſphere to ſurmount. Again, Earthquakes, and thoſe loud Noiſes, which accompany them, are merely the Effects of Rarefaction.

It may, perhaps, be alledged, that the Air produces theſe Effects no otherwiſe, than as it is put into Motion, by the Saltpetre, and Sulphur, which are found in the Bowels of the Earth; for as much as theſe Materials are endued with a certain Power, excluſive of which, the Rarefaction of the Air would by no Means be ſufficient; and that therefore Gunpowder is always in Reality, the ſole Cauſe of thoſe Effects, which we are deſirous of attributing to Air only. But though it may be juſtly queſtioned whether theſe Materials, ſtand poſſeſſed of the ſeveral Virtues imagined, it is not however pretended, but that the ſame Effects may be produced by Rarefaction alone, independent of what is found in the Compoſition of Gunpowder. Experience demonſtrates, that the Heat of boiling Water augments the elaſtic Force of the Air one third. If a hollow Body, replete with Air and well ſtopped, be put into boiling Water, till this Air be rarified to a certain Degree; it's elaſtic Force will break this Body, provided the Preſſure of its Parts be leſs, than the Preſſure of the confined Air; as I have proved by putting thick Glaſs Bottles, well ſtopped, into boiling Water; ſuch Bottles inſtantly burſting in Pieces, notwithſtanding they contained nothing but Air. But the Heat of boiling Water is trifling, when compared with that of a large Fire. Therefore it happens, that if a hollow Globe of Copper or Iron, well ſtopped, wherein a little ſubtile Fluid is incloſed to accelerate the Rarefaction of the Air, be put into ſuch Water, it burſts in Pieces with a loud Report like a ſmall Bomb. But I imagine, enough has been ſaid on this Subject, concerning the Air, for any Perſon to comprehend what I have to advance concerning Gunpowder. Proceed we therefore to examine the three Materials of which it is compoſed, reſerved for the Argument of our

SECOND HEAD. Chemiſts agree, that there is an inflammable and oily Subſtance diffuſed in all mixed Bodies, which is what they commonly term Sulphur; and their Principles are, undoubtedly, juſt: Since Wood, and other combuſtible Bodies, are only reducible to Flame and Coals, as they contain certain bituminous Particles, extracted from the Earth. They likewiſe admit, that there is, generally, a Salt incorporated in all Subſtances; and, indeed, this is what appears in the major Part of thoſe Bodies, that are naturally ſalt, particularly the Earth; from whence we cannot, in the leaſt, doubt, but that it communicates this Quality to Plants and other Vegetables.

THIS Salt is either fixed or volatile. Fixed Salt has not in itſelf any Motion, and, therefore, of courſe, cannot communicate it to other Bodies, with which it is mixed; on the contrary, it actually obſtructs the Action of combuſtible Subſtances. Volatile Salt is intirely different from the former. For as it is compoſed of ſuch Particles as are of a fine looſe Contexture, and what contain withal a great Quantity of ſubtile Air; ſo, when this Salt is united to the oily Subſtance of mix'd Bodies, it renders it much apter to catch Fire, than it would do, were it deprived of this Salt. And, notwithſtanding, this Salt is not inflammable of itſelf; yet has it the Property to looſen and exhale the ſulphureous Particles, in order to render them more ſuſceptible of Motion and

Inflammation. For the incloſed Air being rarified, as the Heat unbends it's Spring, it diſengages on all Sides the Particles that confined it, and looſens the groſſer Parts, which obſtructed its Motion; while the oily Particles being thus ſet at Liberty, move forward with great Velocity. Having then the above Principles before us, they will readily ſerve as a good Baſis on which to explain more particularly, the Nature of Sulphur, Saltpetre, and Charcoal.

SALTPETRE, which makes ſo ſurprizing an Appearance, is no more than a Salt mixed with a Quantity of thin Air; nevertheleſs moſt People entertain a very different Idea of it: They imagine it to be an inflammable Subſtance, endued with ſome extraordinary and inconceivable Quality. I am confident, that no Perſon ever ſaw it burn; for Saltpetre, being a mere Salt, cannot be combuſtible. But why, ſay they, ſhould there immediately ariſe a great Flame, upon its being thrown into the Fire? If Saltpetre were not combuſtible, nothing like this could happen. Indeed, as it ſeems to take Fire, it looks, as if what I had juſt alledged, were deſtitute of Proof. However, upon due Obſervation, it will be found, that this Fire does not, in the leaſt, proceed from the Saltpetre, but from the burning Coals, on which it is thrown. Becauſe the Saltpetre immediately agitates the ſulphureous Particles of the Coals, and not being able to exhale itſelf, it is obliged to yield to this Agitation; the Truth of which evidently appears from hence, that if, inſtead of throwing it on the Coals, it is held over a great Flame, it will be ſo far from taking Fire, that there will not appear the leaſt Spark. Again, if ſome of it be put into a red-hot Shovel, inſtead of burning, it will be found to turn to Water; and if this Fluid be left to cool, it will again condenſe as before. But what happens, when the Saltpetre is become Fluid through Heat, whether in a Crucible, or red-hot Iron-Ladle, is, that if a Piece of Wood be thrown into it, it inſtantly takes Fire, and conſumes without the leaſt Remainder; nor can it be otherwiſe: For the ſubtile Air contained in this Fluid, moves with infinite Velocity; penetrates the Pores of the Wood; extracts the oily Subſtance, which only requires Motion to ſet it on Fire; while the groſſer Particles are agitated with ſuch Violence by thoſe of the Fluid, that at laſt they become imperceptible. But farther to demonſtrate, that Saltpetre is not inflammable, but only a mere Salt, notwithſtanding a ſo generally received Prepoſſeſſion to the contrary, it is notorious, that if it be pulverized with Sulphur, and this Mixture be put on the Fire in a Crucible, it will exhale a great white Flame, which will diſſipate with the ſubtile Air of the Saltpetre, and this being evaporated, there will remain only a Salt at the Bottom of the Crucible, which is a whitiſh Subſtance, termed by Chemiſts *Sal Polychreſtum.*

Sulphur, ſuch as is uſed in Gunpowder, ſhould be conſidered as a Compound of Oil and fixed Salt, which is eaſily known by making the Analyſis. If Sulphur was only an Oil, it would exhale a great white Flame like other oily Subſtances; but the fixed Salt, with which it is mixed, preventing it from riſing, it produces only a little bluiſh Flame; and on the contrary, if a volatile Salt be put into it, it will then exhale a great white Flame with a Report.

Since, it is barely neceſſary that we heat the Air, to rarify it to the ſame Degree, which Gunpowder does; if pulverized Sulphur took Fire inſtantaneouſly, it would of itſelf alone produce all the the Effects of Gunpowder; but as we have already ſeen, that to render it more active, we have nothing to do, but to add Saltpetre to it; it appears that a Powder compounded of theſe two Ingredients only, will perfectly effect this Rarefaction. It is, however, to be obſerved, that when the inflamed Sulphur comes to heat the ſubtile Air of the Saltpetre, wherewith it is mixed; this laſt inſtantly diffuſes ſo violent and ſudden a Wind, that while it has the Advantage of rendering the Flame of the Sulphur more active, it has likewiſe the Diſadvantage of extinguiſhing it the next Moment, unleſs ſome other Cauſe contributes to the Continuance of the Fire. It is therefore obſervable, that, when a Train of Powder, compoſed of Sulphur and Saltpetre, is laid and ſet on Fire, it raiſes a Flame, which inſtantly goes out, unleſs the Fire made uſe of to light this Powder, be immediately applied to the whole Length of the Train. Now, to prevent this, a Subſtance muſt be found, which has the Property eaſily to catch Fire; and which, inſtead of being extinguiſh'd by the two violent Agitation of the Saltpetre, will only catch Fire the more readily: And this is the Property of Charcoal, when incorporated with Sulphur and Saltpetre.

The beſt Charcoal for Gunpowder is that of the Wood of *Bourdaine*. They cut it, and take off the Bark directly, and after it is dried, burn it. But to underſtand fully, the Manner of it's being converted into Charcoal, it muſt be obſerved, that in general, Wood is compoſed of an Infinity of minute Fibres, which being interwoven, leave ſeveral Spaces between their Parts, for forming the Pores. Before it is cut, all theſe Pores are full of Sap, which is an oily Fluid, mixed with much ſubtile Matter, giving it Motion, and cauſing Circulation; but when it is dry, this Fluid condenſes and remains fixed: And as ſoon as the Wood receives the Influence of the Heat, the Air contained in it's Pores, animates the Oil, which exhales itſelf, and takes Fire as ſoon as it finds itſelf ſufficiently diſengaged from the groſs Particles that obſtructed it's riſing.

If the Fire continues burning ſome Time, there will remain only thoſe ſmall Fibres of the Wood, we have juſt ſpoken of, as the Materials compoſing the Subſtance of the Charcoal, which is then carefully to be extinguiſhed. For if it burns too long, the ſmall Fibres are deſtroyed and the whole reduced to Aſhes, on which the Heat makes no Impreſſion: whereas, proportionally, as the Subſtance of theſe Branches is kept together, they yet retain a greater Quantity of this oily Subſtance, as Experience confirms; becauſe, when, after their being extinguiſh'd, ſome of the Powder is thrown into a red-hot Shovel, there preſently ariſes ſtood of any Quantity whatever; ſince it is only an infinite Repetition of the ſame Thing. It is certain, that the greater Part of the Grains will not be equally compounded of theſe three Materials, ſome being found to contain more Sulphur or Saltpetre than others; but theſe Differences cannot cauſe any Alteration in Practice, becauſe, when the Powder is once ſet on Fire, they will always mix themſelves equally.—Since the Queſtion before us, is only how we may rarify the Air contained in a Mine or Gun, when we can carry this Rarefaction to ſuch a certain Degree, it produces all thoſe Effects, that are uſually attributed to Gunpowder; which, however, would only be a trifling Thing, as extraordinary as it may ſeem, without the Elaſticity of the Air; for as much as it is certain, that this Powder has ſcarce any Effect *in Vacuo*. Being thus ſufficiently informed in the Nature of Gunpowder, it now remains that we ſhew in what Manner it takes Fire, which is our

THIRD HEAD. Whatever is tranſacted in Nature, requires a certain Space of Time for the Performance. A Flaſh of Lightning, for Inſtance, ſpreads a ſudden Light, which vaniſhes as ſoon as it is formed; but ſhort as the Time for perceiving it may be, it is ſtill poſſible to conceive a ſhorter; and that aſſigned to a Flaſh of Lightning, may be ſuppoſed divided into a Number of equal Times, in each of which, ſomething yet more ſudden might intervene. In like Manner, though a certain Quantity of Gunpowder takes Fire with a Velocity ſeemingly imperceptible; yet the Mind cannot but obſerve, that there is ſtill an Interval, between the Inſtant when it takes Fire, and that wherein it is wholly inflamed. It may then be conceived, that between the firſt and laſt Inſtant, wherein the Powder begins to take Fire, and becomes wholly inflamed, a Number of other Times interpoſed, during each of which a determinate Quantity of Powder takes Fire: In ſuch Sort that, if, in the firſt Inſtant, a Grain of Powder only takes Fire, in the ſecond a Number of others, which are contiguous, will be inflamed; in the third, theſe two will ſet Fire to a ſtill greater Number; becauſe all of them together occupy a larger Space than the firſt, and conſequently anſwer to a greater Number of Grains than what either of them compoſe ſeparately: While thoſe of the third Inſtant, again, will act in like manner with regard to other Grains, whoſe Quantity ſhall be ſtill found to increaſe. But to evince more clearly by what Law theſe ſeveral Grains become inflamed, let us have

Recourſe

ariſes a ſmall bluiſh Flame. Now, Charcoal, in this State, is of excellent Uſe for Gunpowder: For as it takes Fire with great Celerity, and is very light; ſo, be it agitated ever ſo little, it immediately inflames the Materials, when they come to receive the Influence of its Fire. It is true, that, being agitated by the Saltpetre, the Charcoal, is ſoon deſtroyed; but it ſubſiſts long enough to perform its proper Function. However, leſt it ſhould be queſtioned, that Charcoal is endued with a Property eſſential to Gunpowder, and ſuch as is peculiar to itſelf; I ſhall again obſerve, that its whole Buſineſs, on its being mixed with the Sulphur and Saltpetre, is, only to continue the Fire; and yet Tinder, or the Pith of Eldar well dried, may be uſed in its ſtead, with which very good Powder is made; becauſe theſe Materials catch Fire directly, and continue it in like Manner: But Charcoal is, doubtleſs, preferable, as being common, and eaſily prepared; whereas any other Materials would, undeniably, require more Trouble.

If we were now to conſider a Grain of Gunpowder compoſed of a Quantity of other Grains, infinitely ſmall, of Saltpetre, Sulphur, and Charcoal, equally extended from the Centre to the Circumference, in proportion to the

Number of each Species; it is plain that, ſetting Fire to any one Part of the Surface of this Grain, the Sulphur, as being the moſt active, will take Fire firſt, and after that the Charcoal; upon which the Air, contained in the ſmall contiguous Grains of the Saltpetre, will preſently rarify, and put the Flame of the Sulphur, and the Fire of the Charcoal, into Motion; but this Air will not unbend its Spring without the Intervention of ſome little Force, ſuch Application being neceſſary to looſen the other contiguous Grains, where the Fire has not yet communicated itſelf: And if, in this little Shock the Grains of Powder, which were not inflamed, ſhould happen to be ſeparated; yet, if the Charcoal be once lighted, it will communicate Fire to them: While the Saltpetre, on its Part, will continue to agitate a Number of Grains, Part of which will be on Fire, and Part not; but then, as they will be found to claſh together by the Motion, which the ſubtile Air will neceſſarily give them, they will ſo effectually communicate the Fire of the Sulphur and Charcoal, that all theſe ſmall Grains will, at laſt, be intirely inflamed.

WHAT we have here advanced concerning a ſingle Grain of Gunpowder, may be under-

Recourſe to a Globe filled with Powder; ſo that ſetting it on Fire at the Center, the Inflammation ſhall be communicated in a circular Form. We will then ſuppoſe, that the Time requiſite for this Powder wholly to take Fire, is expreſſed by the Radius, divided into a Number of equal Parts; as, for Example, an hundred, which we will call Moments, in order to obſerve what Changes the Powder will undergo in each of them. That being granted, let us ſuppoſe, at the Center, a ſmall Globe of Powder, whoſe Radius ſhall be the firſt of thoſe equal Parts, we juſt now mentioned, that is, one Moment: After this another, whoſe Radius ſhall be two Moments; after this ſecond, a third, whoſe Radius ſhall be three Moments; in ſhort, let us ſuppoſe, as many ſucceeding Globes, as there are Terms in an arithmetical Progreſſion of natural Numbers 1, 2, 3, 4, 5, 6, *&c.* the greateſt whereof ſhall be 100. Thus theſe Globes continually increaſing, will have the Terms of this Progreſſion for their Radii; but that which conſtitutes the Difference between the firſt and ſecond Globe, is a Shell; the Difference between the ſecond and third, is again a Shell of the ſame Thickneſs; in ſhort, all theſe Globes, beginning with the center Globe, proceed increaſing by a Shell, whoſe Thickneſs remains invariably the ſame. Wherefore, taking the center Globe for a Shell, it may be affirmed, that there are as many Shells as Moments. If it be now ſuppoſed for a little while, that the Grains of Powder, which compoſe the ſecond Shell, are ſet on Fire in the ſecond Moment; the next, in the third; and ſo of the reſt, till we come to the greateſt Radius; it may then be ſaid, that there were as many Shells ſet on Fire, as there were Moments elapſed from the Globe's being firſt inflamed. But theſe Shells form Spheres, and theſe Spheres being in the Ratio of the Cubes of their Radii; the Quantities of Powder fired at the End of a determinate Number of Moments, will be in the Ratio of the Cubes of thoſe Moments: Therefore, according to this Hypotheſis, ſince a Heap of Powder always takes Fire, in the Form of a Sphere, it may be alledged, on the whole, that the Quantities of Powder inflamed in any determinate Periods, are in the Ratio of the Cubes of thoſe Periods. Now, as all theſe Globes have the Terms of an arithmetical Progreſſion 1, 2, 3, 4, 5, 6, *&c.* for their Radii; the Quantities of Powder inflamed ſucceſſively, will therefore, at the End of each Time, be as the Cubes of the Terms of an arithmetical Progreſſion: So that if one Ounce of Powder takes Fire in the firſt Moment, there will be eight inflamed at the,

the End of the ſecond; 27 at the End of the third; 64 at the End of the fourth, and ſo on. But if any Perſon would know, how much is inflamed in each particular Moment, it muſt be conſidered, that the Quantities of Powder, correſponding to each of the Times, were expreſs'd by Shells; and that theſe Shells are the Difference of Spheres; ſo that, conſequently, theſe Shells will be in the ſame Ratio as the Difference of the Cubes of the Radii of the ſame Spheres. Whence it follows, that if one Ounce of Powder takes Fire in the firſt Moment, there will be 7 inflamed in the ſecond; 19 in the third; 37 in the fourth, and ſo on according to the Difference of the Cubes 8, 27, 64, 125, *&c.*

I ſuppoſed above, that the Shells, having all the ſame Thickneſs, ought to be inflamed in equal Times: But this Concluſion is not juſt. For the Powder that takes Fire in the firſt Moment, not being annihilated, when that, lighted in the ſecond, proceeds to ſet Fire to the third Shell; it happens, that That, which is inflamed in the firſt Moment, uniting itſelf to that ſet on Fire in the ſecond; occaſions a much greater Quantity's being inflamed in the third, than in both the forementioned Times;

that is to ſay, that before the ſecond Moment is elapſed, the Action of the Powder at firſt ſet on Fire, has already extended its Influence to the third Shell. In like manner, before the End of the third Moment, a great Part of the Powder in the third Shell has already took Fire; and ſo on to each ſucceeding Shell, which takes Fire with a far greater Velocity, than we have aſſigned it: Conſequently, the Quantities of Powder, which take Fire, progreſſively, in each Moment, will greatly exceed the Difference of the Times elapſed; ſince they will be in the compound Ratio of the Difference of the Cubes of the Times, and the Quantity of Powder fired from the firſt; provided the Action of the Powder, firſt ſet on Fire, always ſubſiſts. So that it may be affirmed, that the Quantities of Powder, which take Fire in each Moment, are at leaſt in the Ratio of the Squares of the fourth Powers, and, it may be, indeed, of the fifth and ſixth of the Times elapſed from its firſt Inflammation; it is, however, difficult to determine preciſely in this Caſe. Now ſince it is certain, that the Quantities of Powder, which take Fire at the End of a determinate Number of Moments, exceed what we expreſs by the Ratio of the Cubes of thoſe Times; we may without Fear of inlarging, follow this Rule as indiſputable, and the rather, becauſe it is very proper to fix the Imagination.

Supposing us now to have made an Experiment, wherein it was found, that 20 Pounds of Powder required two Seconds to ſet all of it on Fire, when put together in an Heap, according to the precedent Hypotheſis: In order to know what Quantity takes Fire in five Seconds, you muſt ſay as the Cube of two Seconds, which is 8, is to 20 Pounds of Powder; ſo is the Cube of 5, which is 125, to the Quantity of Powder, which is to take Fire in five Seconds; which will be found 312 Pounds 8 Ounces; but it will in fact, be much greater: Since it is evident, that a greater Quantity will take Fire in that Space of Time. In like manner, ſhould the Number of Seconds be required to inflame 500 Pounds of Powder, upon Suppoſition that 20 Pounds always demanded two Seconds; you muſt ſay, as 20 Pounds is to 8, ſo is 500 Pounds to the Cube of the Time ſought; which will be found to be 200: And as the Cube Root of this Number is ſomething leſs than 6, the Time required will therefore be about 6 Seconds; which will, however, be certainly leſs, than the preſent Operation requires: For which Reaſon, I don't cite it as a Rule to be followed, but only as it may be of Service for deducing very uſeful Inferences.

LET us then be no longer ſurpriſed, that two Pounds of Powder have a much greater Effect, in proportion, than one Pound: Becauſe, while it remains confined, its greateſt Effort muſt neceſſarily depend on the Largeneſs of the Quantity inflamed at the ſame Time; for the more the Springs of the Air unbend themſelves in Quantity, the more alſo will their active Force be found to prevail: And, as we have ſeen above, that a much longer Time was neceſſary, in Proportion, for one Pound to take Fire, than for two; its Forces will be much more united in two Pounds, than it can be in one; ſince, by how much the leſs Time is required for a determinate Quantity of Powder to produce its Effect, by ſo much the leſs, will that Quantity, which firſt took Fire, be evidently weaken'd. For as the Action of this firſt ſubſiſts but a very ſmall Portion of Time, it muſt be nearly ſpent, ſuppoſing a ſenſible Interval obtains between its Inflammation, and that which takes Fire laſt.

HOWEVER, it is to be obſerved, that, ſubſtituting the Numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, to expreſs the Times, in the Courſe of which the Powder takes Fire; if, one Pound, for Inſtance, was to be inflamed in the firſt Moment, and that it's Power were almoſt ſpent in the tenth Moment; as a much greater Quantity than 271 Pounds will be ſet on Fire in the tenth Moment, the Force acquired in this laſt Moment, is by no Means to be compared with that of the firſt Moment, which would now be conſiderably diminiſhed: Whence it follows, that, the more Powder there is to be inflamed, the greater alſo will be the Forces acquired, in Proportion to thoſe, which are ſpent in having been produced firſt. It muſt not, however, from hence be imagined, that the Powder, which firſt took Fire, does not contribute to the Effect of the whole; ſince, even when it is intirely extinct, it has not leſs rarified the circumambient Air, which Air proceeds to acquire new Forces from the Beginning to the End of the Inflammation: And we have before ſeen, that the Forces acquired in each Moment, or, if you will, the Degree of Rarefaction, exceed the Ratio of the Cubes of the Times elapſed: But this takes Place, as before remarked, no longer, than while the Capacity of the Chamber, where the Powder is lodged, does not augment. For as ſoon as the Air can expand itſelf, this Expanſion is ſo far a Diminution of

its

its elaſtic Force, which would act with all it's Power, provided the ſurrounding Bodies did not yield till the laſt Moment of the total Inflammation. But as it is ſcarcely poſſible, that this ſhould happen, it plainly ſhews the Defect of thoſe Fire-Arms, which are too ſhort, eſpecially of Cannon. For ſince, according to our Principle, the Quantity of Powder, which takes Fire in the laſt Moments, greatly exceeds that, which acts at firſt; it evidently appears, that a Bullet, or Ball, does not receive near the whole Force of the Powder; and, indeed, it would be much, if it received the one half. It is true, that the Length of Guns and Piſtols may be leſſened, by giving them the ſame Property as Carabines; that is, by making them in ſuch a Manner, that the Ball, meeting with a great Reſiſtance on account of the Channels, or Furrows, ſhall receive as much Force, as if it had paſſed through a longer Cannon, which was not channeled, or furrowed. Where ſpheric Chambers can be made to Pieces of Artillery, the Powder lies compacter, and catches Fire much ſooner than in cylindric Chambers. But this Method can only take Place in Mortars; ſince ſpherical Chambers for Cannon, will be liable to ſome Inconveniencies. And for this Reaſon, probably, they have generally adhered to the antient Cuſtom, ſo juſtly applauded, in proportioning the Length of Cannon, which appears to be founded on geometrical Principles. And there is Room to Queſtion, whether if, in our late Alterations, we have at laſt, purſued a better Method. In treating of Cannon, it muſt be confeſſed, we have had very extraordinary Idea's reſpecting the Figure, which a Chamber ought to have for producing the greateſt Effects. Is there any Chamber, for Example, worſe contrived than that, which they call Conic, becauſe it grows narrower towards the Breech, like the Fruſtum of a Cone? If they imagined by that Step, to augment the Amplitude, they were groſly miſtaken: For, according to all we have hitherto ſaid, the ſame Quantity of Powder can produce no great Effect, but in Proportion to the Time it requires for taking Fire; and to obtain this End, the Fire ſhould be applied as near the Center as poſſible, that ſo it may communicate itſelf in a circular Manner, and ſet Fire to the ſeveral Parts of the Powder at the ſame Time; which, as we ſhall hereafter ſhew, cannot be done in a conic Chamber.

If we form a Cylinder and a Cone, or if you pleaſe, the Fruſtum of a Cone, of an equal Quantity of Powder, whoſe Baſes are equal; Firing one, *h. e.* the Cone, at the Vertex, and the other at the Centre of its upper Baſe; the Cylinder will be much ſooner conſumed than the Cone; becauſe there are fewer Grains of Powder, which begin to take Fire in the Cone, than in the Cylinder: Beſides that, the Fire, in it's Progreſs is longer in reaching the Baſe of the Cone, than that of the Cylinder. Thus, in a conic Chamber, though the Vent be not at the very Extremity of the Fruſtum, towards the Breech; it is yet evident, that the Powder takes a longer Time in Firing, than the ſame Quantity does in a cylindric Chamber; conſequently, the Effect cannot but be much leſs: Becauſe it happens here, with regard to theſe two different Chambers, as we have obſerved above, in reference to the Cone, and the Cylinder.

I could relate many other Caſes, wherein Perſons, who have thought they could ſucceed better, have been deceived, for want of giving themſelves the Trouble of inquiring into the Laws, by which Powder takes Fire. For it muſt not be imagined, that any one can reaſon judiciouſly on the Effects it produces in Fire-Arms, or on the Art of throwing Shells, without ſome Knowledge of this Kind. In ſhort, ſince I firſt applied myſelf to this Study, I have diſcovered the Reaſon of many Things, which I could

I could form but a very imperfect Judgment of before. When I calculated, in 1725, the Table, which is the main Deſign of my Treatiſe intitled the *French Bombardier*, I made Experiments ſeveral Days together, which ſucceeded pretty well at certain Times; the Shells falling very near the Diſtance deſigned: But what ſurprized me, was, to obſerve that the Shells, which I fired in the Evening, after Sun-ſet, fell a great Way beyond the proper Diſtance. Bombardiers ſay, that this ariſes from the Heat of the Mortar; becauſe after it has been diſcharged ſeveral Times, they pretend, that the Powder muſt needs acquire greater Force. At other Times, when the Atmoſphere was more denſe, the Amplitudes became ſtill greater. Some Days after, when the Sun ſhone with conſiderable Force, they became leſs, and ſometimes approached nearer their firſt Diſtance. If I fired in the Cool of the Morning, the Shells went farther, than in any other Part of the Day. I then reflected with myſelf: That, ſince the Effects of Gunpowder were to be determined by the different Denſities of the Air, at Evening and Morning; it muſt therefore be denſer at thoſe Times, than in the Middle of the Day; and ſtill more condenſed, when the Atmoſphere was charged with Vapours; ſo that having hereby attained a greater elaſtic Force, the Powder could not but throw a Shell farther; and that, on the contrary, when it had been greatly dilated by Heat, it's Elaſticity would conſequently become leſs. I am now no longer ſurprized, that in Powder-Proofs of the ſame Manufacture, deſigned for the King's Magazines, thoſe Proofs made from the ſame Barrel, ſhould throw the Globe, uſed for this Purpoſe, farther at one Time, than at another: For as much as the Air may be conſiderably changed from one Day to the next, and even between the Morning and Evening of the ſame Day. In order therefore to be aſſured, whether theſe different Flights ariſe naturally from the Powder, it will be proper to obſerve, if the Barometer, or Thermometer, has not changed it's Degree.

It may, perhaps, be thought by no Means ſufficient, that we know the Source of the various Accidents, which happen to Powder; ſince, it is certain, that the main Buſineſs is to prevent them. A Method for this alſo is what I propoſe; nor does the Acquiſition appear to me impoſſible. It is a great Point gained, to know whence theſe Difficulties ariſe; Induſtry, and Time, will at laſt, point out the proper Means for ſurmounting them. But to this End it will be neceſſary, that we reaſon from Effects to their Cauſes; for unleſs we purſue this Plan, we ſhall find, that the plaineſt Things will be as far removed from our Knowledge under our laſt Reſearches, as they were at the firſt; and, conſequently, that they will ever wear the ſame diſagreeable Aſpect.

As the ſame Effects, without doubt, ought to ariſe from the Cannon, as from the Mortar; it ſhould ſeem, that they are in the wrong, who believe, that the greater Degree of Heat a Cannon has acquired, by reaſon of its being fired ſeveral Times ſucceſſively, the greater will be the Range of the Shot: Since, as I have proved by Experiments, the firſt Shot goes farther, than any of thoſe which ſucceed it. For, when a Cannon has remained ſome Time without Firing, the Air, which is contain'd in the Chaſe, is nearly the ſame with that which we breathe; it ſhould, indeed, be rather denſer; becauſe it is not ſo much rarified as that, which receives the Influence of the Sun. Therefore, when a Piece, in this Condition, is diſcharged, the Shot goes to a certain Diſtance; but on it's being fired, no ſooner has the Fire arrived at the Powder, than the Air, contained between the Breech and the Shot, rarifies, and drives out the Wad and Shot, which preſs forward the Air contained from the ſecond Wad to the Mouth; as ſoon then as the Ball has made it's Exit, the Air, which had been before expelled, makes it's Return by the Mouth of the Piece and the Vent, but not in ſo great a Quantity as at firſt: For that which remained in the Piece immediately after Firing, has been extremely rarified, and will remain in this State ſo much the longer, as the Piece is hotter, by the great Number of repeated Firings. Now, this rarified Air makes a Reſiſtance againſt that, which would re-enter; therefore, when they Fire again inſtantly, it happens, that the Air, which is mixed with the Powder in the Chamber, is not near ſo denſe as before, and that it has conſequently leſs elaſtic Force, and will always, on every Firing, ſtill ſuffer a gradual Diminution, as the Degree of Heat in the Metal continually increaſes. It is, nevertheleſs, to be obſerved, that, if they Fire with Powder, which has contracted a little Dampneſs, the Shots which are fired directly after the firſt, go nearly the ſame Diſtance as the firſt; eſpecially, if the Piece remains charged ſome Minutes; becauſe it may dry in conſequence of the Heat of the Metal, take Fire quicker, and regain by it's Velocity, what the Spring of the Air had loſt: But this can only happen in a few of the firſt Shots, ſince at length, as I before obſerved, the Piece being very hot, the Amplitudes will neceſſarily become ſhorter.

It has been objected to me, that in Sieges where the Cannon fire ſucceſſively, they have been obliged to diminiſh the Charge; becauſe the Heat of the Metal continually increaſing, a ſmaller Quantity of Powder, by this Means, acquired an additional Force equivalent to that of a full Charge. But I can ſcarce believe, that in thoſe Caſes, Obſervations were made with ſuch Exactneſs, as might enable them to determine, whether the Ball was carried with a greater Force, proportionally as the Piece grew hotter: I rather think, that they were neceſſitated to diminiſh the Charge, in order to ſpare the Metal, which ſuffers greatly, if always charged with the ſame Quantity; and it is for this Reaſon, that they conſtantly allow the Pieces Time for cooling.

From all theſe Circumſtances it appears, that the Powder, which is incloſed in the Chamber of a Mine, provided it does not remain ſo long as to contract any Dampneſs, ought to produce a far greater Effect, than if it was lodged in any other Place, where there were the ſame Obſtacles to ſurmount; but where the Air, however, would not be ſo denſe, as it is in low Places: Conſequently, the larger the Line of leaſt Reſiſtance of a Mine is, the greater will be the Effect of the Powder. And this alſo is the Reaſon, why ſubterraneous Fires make ſuch prodigious *Conatus's*, and break out with ſuch loud Reports; the Air being there vaſtly denſer than on the Surface of the Earth. But there are ſeveral other Things to be conſidered, relating to the Theory of Mines, which admit of no Explication, excepting by that of Gunpowder.

After having wrote this Theory of Gunpowder, I began to think, that it might be neceſſary, for my own Inſtruction, to communicate it to the Learned, in order to get their Sentiments upon it. I have accordingly diſperſed ſeveral Copies in *France*, and in foreign Countries, having ſent them particularly to the royal Academies of *England* and *Pruſſia*, who have aſſured me of their Approbation. The Academy of *Pruſſia* have eſteem'd it worthy a *Latin* Tranſlation, which has been printed in the Collection of their Memoirs. Nevertheleſs, many Perſons have informed me, that they were not fully perſuaded, that the firſt Shot went farther than the ſucceeding ones, when the Metal was hotter. I was reſolved to be convinced of this by new Experiments; the following therefore is the Reſult of them, which I annex, to ſatisfy thoſe, who in reading this Memoir, may ſtill entertain the like Scruple.

The better to illuſtrate the Manner in which theſe Experiments were made, it is proper I ſhould obſerve, that there is an Ordonnance of the King, by which he commands, that the Gunpowder Manufactured in his Kingdom ſhall not be eſteemed Proof, 'till three Ounces, which is the Charge of a Proof-Mortar, elevated always at 45 Degrees, and of 8 Inches Diameter, whoſe Chamber is Cylindric, ſhall throw a Globe, of 60 Pounds Weight, to the Diſtance of 60 Toiſes: It is received, however, provided it does not fall ſhort of 55 Toiſes.

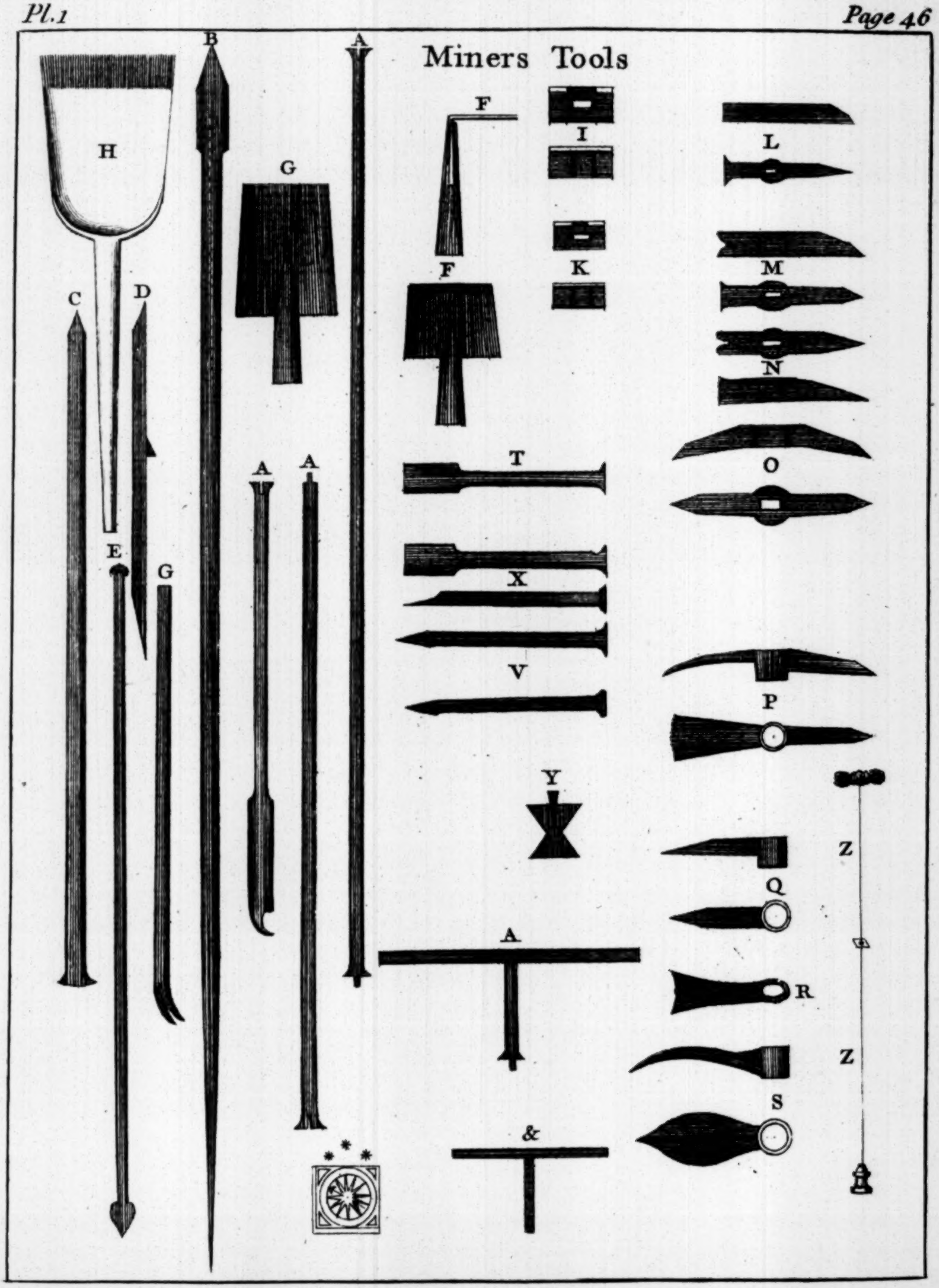
For making theſe Experiments with the utmoſt Exactneſs, ſeveral Charges of three Ounces of Powder were nicely weighed, each incloſed, ſeparately, in little Barrels made for that Purpoſe: This Quantity was put into the Proof-Mortar with a Funnel, ſo that the Chamber ſhould be always full: And in this Manner were the Experiments, which I am going to relate, made, with the greateſt Care and Circumſpection, the Preparations being ſtill the ſame at one Time, as at another.

On the 4th of *Auguſt*, 1729, at 5 o'Clock in the Morning, I was at the Proof-Place with the Chevalier *d'Aboville*, Superintendent of this School, together with ſeveral other Artillery Officers. The preceding Night had been very cool, and there was then a thick Fog. A Proof-Mortar was charged, which threw it's Globe 72 Toiſes; every Body was greatly ſurprized to ſee it go ſo far, for it commonly went but 60 at the fartheſt. I affirm'd however, that it would not be thus, when a few Shots had been fired. In ſhort, the ſecond Time it went but 68 Toiſes, the third 66, the fourth 65, the fifth and ſixth nearly the ſame, the ſeventh 64, the eighth 63, the ninth 62. 5. the tenth 61, the eleventh the ſame, the twelfth 60, the thirteenth 59, the fourteenth 57, and five or ſix ſucceeding Globes fell always, nearly, at 58 Toiſes. I have to add, moreover, that, proportionally as the Amplitudes diminiſh'd, the Sun rarified the Air, and the Fog diſperſed; the laſt Shot being fired about 10 or 11 o'Clock.

As Gunpowder always cauſes a thick Moiſture, particular Care was taken, every Time they fired, to ſpunge the Mortar perfectly well. Neverthleſs, there are thoſe who aſſert, that if the firſt Shot go farther than the reſt, it is, poſſibly, occaſion'd by the Chambers not being ſo thoroughly throughly ſpunged afterwards, but that there might ſtill remain much Dampneſs, which, communicating itſelf to the Powder, might deprive it of Part of its Force, For their Satisfaction therefore, lighted Charcoal was put into the Mortar to dry it; after this, it was again charged, to diſcover what would be the Conſequence; becauſe, according to the common Opinion, the Globe ſhould have gone farther than ever, the Metal being ſo hot, as ſcarce to be touched; whereas the Event was, that the Globe went only 56 Toiſes.

The ſame Day, at two in the Afternoon, the Thermometer having roſe 8 Degrees ſince five in the Morning; I fired again in the Heat of the Day: the firſt Shot, inſtead of going 72 Toiſes, went but 61, and the ſucceeding Shot diminiſh'd to 55, by reaſon of the Expanſion of the Air. The following Days, I repeated theſe Experiments at the ſame Hours, and the Reſult came out as before: having fired alſo towards eleven at Night, the Amplitudes conſiderably exceeded thoſe of the Afternoon; but were not ſo great as the firſt in the Morning. And yet, fully to prove, that the Expanſion of the Air conſiderably leſſens the Elaſticity of Gunpowder, I have to add, that, if it be burnt by the Focus of a parabolic glaſs, held in the Sun, it will be obſerved to take Fire with great Difficulty, and with very little Report.

I HAVE only to ſubjoin a word or two concerning the Cauſe of that Humidity, and black Fluid, which is obſerved in Fire-arms, after they have been diſcharged ſeveral times ſucceſſively. It is then known to be nothing more than the Salt of Saltpetre liquefied by the Action of the Sulphur and Charcoal. And it was even by ſearching into the Origin of this Fluid, that I firſt diſcovered, that Saltpetre was not combuſtible; but that it is merely capable of being reduced to Water, when held over the Flame of an intenſe Fire.


Miners Tools

A COMPLETE

TREATISE

OF

MINES.

THE Art of Mining requires a perfect Knowledge both of Fortification and of Geometry; that by theſe previous helps, the Engineer may be qualified to inform himſelf in the Nature of all Heights, Depths, Breadths, and Thickneſſes; to judge perfectly concerning all Slopes and Perpendiculars, whether they be ſuch as are parallel to the Horizon, or ſuch as are Viſual; together with the true Levels of all Kinds of Earths.

To which is likewiſe to be added, a conſummate Skill in the Quality of all Rocks, Earths, and Sands in general; the whole accompanied with a thorough Knowledge in the preciſe Force of all Sorts of Gunpowder.

Explanation of the Plate of Miners Tools.

A, B, *Sounding Augres of ſeveral ſorts.*

C, D, *Different Leavers.*

E, *The Miners Needle for Working in Rocks, to make little Lodgments for Powder, either to blow them up, or to make Excavations in them, and thereby clear the Ways.*

F, *Rake.*

G, *Spade.*

H, *Shovel.*

I, K, *Sledge Hammers.*

L, *Maſons Hammer.*

M, N, O, P, Q, R, S, *Variety of Pick-Axes, Pics, and Mattocks.*

T, V, X, *Different Chiſſels.*

Y, *A Spade to dig the Trenches for the Augets: Theſe Spades ſerve likewiſe to dig Turf.*

Z, *Plummet.*

&, *The Miners Rule.*

⁂ *The Miners Dial.*

The following is the Memoir of an Engineer, founded on ſeveral Experiments.

THE Uncertainty to which he had obſerved Miners always expoſed in the Effect of their Mines, as a Conſequence of their having either over or under charged them, engaged Mr. —— ſome Years ſince, to conſider this Affair with ſome Attention; and after examining the Circumſtances of the Caſe, he imagined, that the Effect of Gunpowder ought to be as certain as that of other moving Forces; a Queſtion, that could only be determined by the Effects ariſing from Mines. He therefore reſolved to apply to Court for the Uſe of ſome 1000 Pounds of Powder, to make the deſigned Experiments, which Favour was accordingly granted, and thereupon the Sieur—— Engineer, at that time, Captain of the Royal Miners, was ſent to attend him.

THE fourth Mine which Mr. —— ſprang, intirely convinced him of the Succeſs of his Method, by obſerving correſpondent Effects in the Excavation of the Soils.

WE know, that the Diameter of the Surface of the Earth raiſed, has been always found double the Altitude of the Earth, when meaſured from the Bottom of the Fourneau to the Surface.

But as there had been no determinate Method for finding the Force, with which the Powder acts upon the Earth ſurrounding the Fourneau, Mr —— ſuppoſed, that the Mine was to be meaſured, by fixing the Space of the Chamber at two Toiſes Diameter, which in reference to that of the Surface, whereof we take the half only, will give us exactly one Toiſe.

Notwithstanding this Meaſure of two Toiſes was a mere Chimera, and taken without the leaſt Foundation, it did not, however, prevent him in reaching the Point in View: For, ſubjecting his future Calculations to this Principle, his Experiments and Operations were continued with ſuch Succeſs, that they were all found to anſwer exactly: So that, after ſpringing the Eighth Mine, there was no farther Proof wanted, excepting that only, which was expreſly reſerved to demonſtrate the Truth of the preceding Operations.

It is therefore, always found, that two Ounces of Powder will raiſe two cubic Feet of Earth: Conſequently, two hundred Ounces, that is, 12 Pounds 8 Ounces, will raiſe 200 cubic Feet, which is nearly a cubic Toiſe; for it wants only 16 cubic Feet: And we might venture to ſay, that it will raiſe even a cubic Toiſe; becauſe, the two hundred Ounces when joined together, cannot but have, in Proportion, a greater Force, than two Ounces, as being evidently an united Force. Here the Rule of Three will ſerve to give us a clearer Idea:

If 2 Oz.—2 Ft.—200 Oz.

2

——

2)400(200 Cubic Feet.

THIS is ſufficient to ſhew us, that, by increaſing or diminiſhing the Quantity of Powder, it is poſſible to blow up any Portion of Earth or Maſonry whatever. But here the Miner ſhould obſerve, that the Powder always acting againſt the weakeſt Part, he ought to be particularly careful, that there be no void Space about his Chamber; and that he proportion his Solid to the Thickneſs of the Earth he would blow up, in the Ratio of 3 to 2.

AND again: That the ſeveral Turnings, he uſes, for advancing his Mine, and through which he is to conduct the Sauciſſon, be well filled with Earth and Dung; and likewiſe, that the Maſonry be in Proportion of the Earth to be blown up, as 3 to 2.

THE Entrance of the Chamber of the Mine, ought to be well ſecured by thick Planks in the Form of a St. *Andrew*'s Croſs; in ſuch Sort,

that

that the whole Frame be quite exact; and care is alſo to be taken, that every little Vacuity or Chaſm be well ſtopped-up with Dung or tempered Earth.

If it ſhould happen ſo unluckily, that while they are advancing a Mine, a Gallery ſhould be found either beneath, or on one Side of their Fourneau; it is abſolutely neceſſary that ſuch Gallery be filled up with the ſtrongeſt Maſonry half as long again as the Height of the Earth; becauſe, if this Precaution be not taken, the Gallery will not only burſt, but likewiſe prevent the Effect of the Mine.

The Powder ſhould always be kept in Sacks, which are to be opened when the Mine is charged, and a ſmall Quantity of the Powder is to be ſtrewed about.

But when a Mine is charged, and not to be Sprang for three or four Days, then the Chamber muſt be boarded, and made like a Cheſt, that the Powder may contract as little Dampneſs as poſſible: Oil-Cloths are excellent upon theſe Occaſions. It muſt be obſerved, that by how much the Quantity of Earth raiſed is greater, by ſo much, likewiſe, is the Effect of the Mine; ſuppoſing it only to have had the due Proportion of Powder.

Powder has the ſame Effect upon Maſonry, that it has upon Earth; which means, that, in

Proportion to the Difference of theſe Bodies, it raiſes either of them with the ſame Activity or Force.

THE Different Sorts of Earth are reducible to theſe four, *viz.*

I. Middling light Soil.
II. Sand.
III. Potters Earth, and,
IV. Clay, or Fullers Earth.

Their Weights here follow: Viz.

	Pounds.
A cubic Foot of middling light Soil weighs commonly, — — —	90
Of Sand, — — — — —	150
Of Potter's Earth, — — — —	100
Of Clay, or Fuller's Earth, — —	115

With regard to Maſonry,

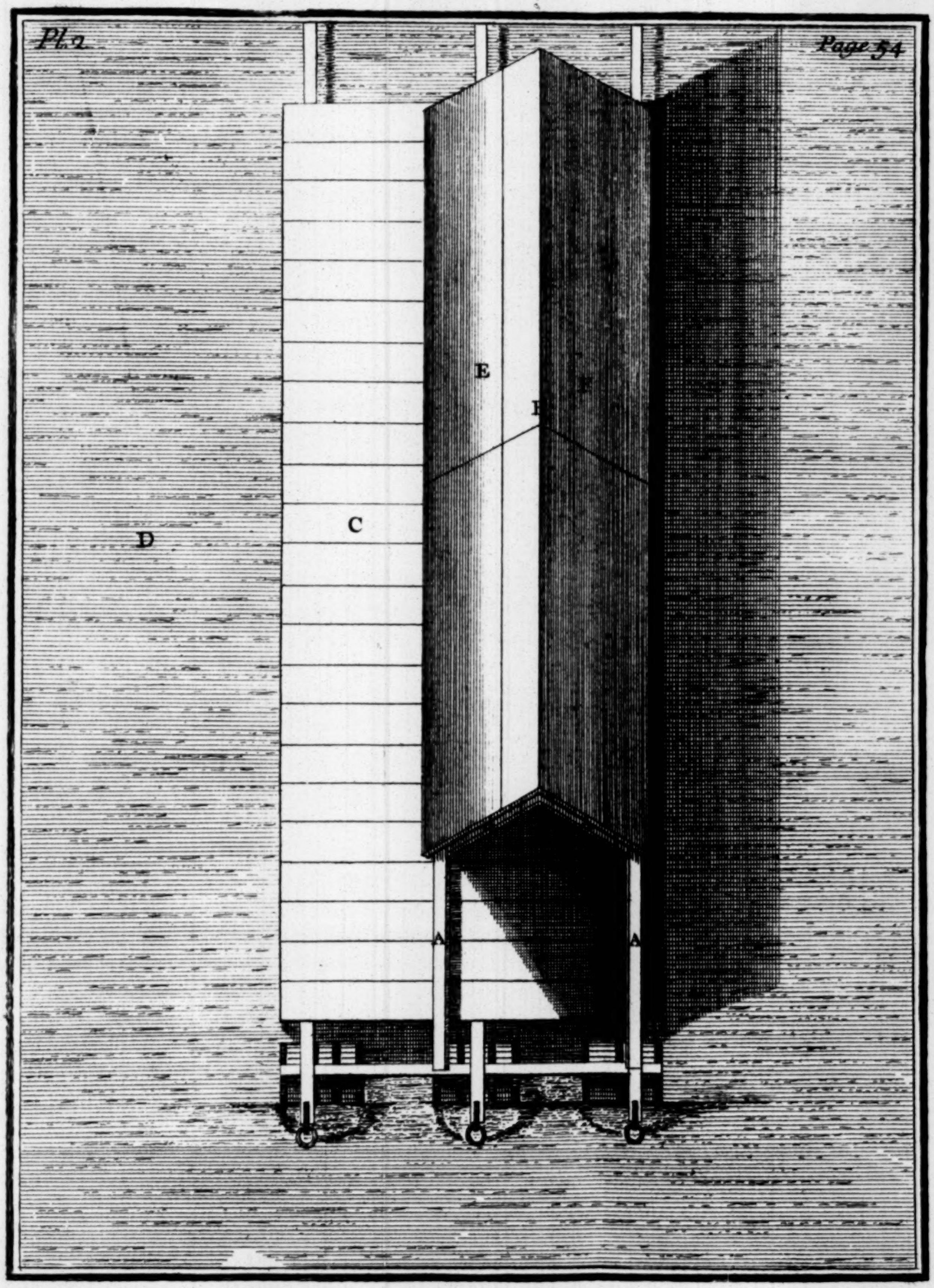
A cubic Foot of white Stone weighs, —	115
Of Flint-Stone, — — — —	120
Of Hard-Stone, as *Graiſſerie of Tournay*,	125
Of Free-Stone, — — — — —	120
Of Brick, — — — — — —	90

THESE Weights are not always the ſame; but vary with the Difference of Countries: The above are ſuch as we find about *Tournay*.

The Method to be obſerved for the Conſtruction of Mines, Fourneaus, Saps, Galleries, Bridges, and Miners Lodgments; founded on a variety of Experiments made by Engineers on ſeveral important Occaſions.

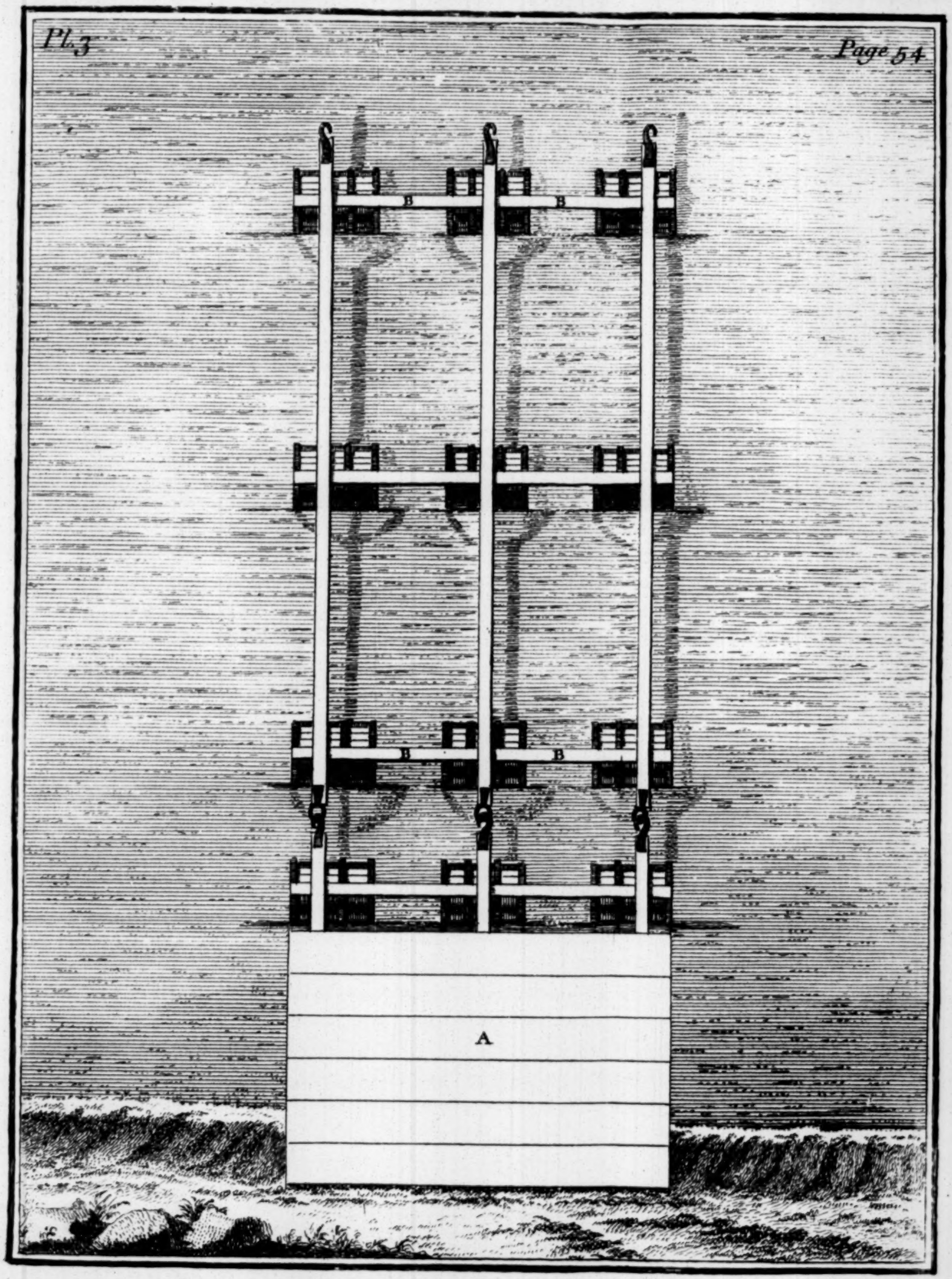
WHEN the Works of a Trench are advanced as far as the Foot of the Counterſcarp of the Work to be attacked, the Sap, having been firſt made, for the Deſcent of the Ditch, there ought to be Places of Arms to the Right and Left of the Ditch, ſufficient to contain the Materials that may be neceſſary for building the Bridge, and the Gallery, where the Miner is to be fixed.

IT is the Duty of the General Officer, who commands the Trench for the Day, to appoint ſuch a Number of Troops for the Places of Arms, as he ſhall think ſufficient to defend the Workmen of the Gallery, and the Miner, from the Aſſaults of the Enemy. All the Materials for erecting the Bridge, and Gallery, having been prepared in the Park of Artillery, by Order of the Grand Maſter, or Lieutenant, who commands; the Captain of the Miners muſt ſee, that they be carried in the Day-time to the Places of Arms, for caſting the Bridge into the Ditch,


Pl. 2
Page 54
D
C
E
B
F
A
A

Pl. 3

Page 54



Ditch, if it is full of Water; or for conſtructing the Gallery at the firſt of the Night; provided the Defences of the Flank, which defend the Face of the Baſtion, or any other Parts oppoſite to thoſe, where they intend to fix the Miner, be firſt intirely demoliſhed by the Cannon; to the End that the Enemy by their Batteries may not have it in their Power to deſtroy the Gallery, which the Beſiegers ſhall make to cover the Paſſage of the Ditch.

IF the Ditch be full of Water, and cannot be drained; a floating Bridge, as large as the Ditch, muſt be uſed; whereon a Gallery * muſt be erected, whoſe Size is to be from four Feet and a half, to five Feet in the Clear, and the Height of it from five to ſix Feet, including the whole; covered on the Ridge with raw Hides, or Tin, to prevent the Enemy's Fire-Works from burning it: For being covered in this Manner, all that is thrown upon it, will directly roll into the Water.

---

* This Gallery is not uſed at preſent. The Miner, now, arrives at the Body of the attacked Work, either by Means of a ſubterraneous Paſſage which he makes under the Ditch, provided the Nature of the Soil admits of it; or elſe, under favour of the Epaulment, which covers the Paſſage of the Ditch. When the Ditch is full of Water, and his Paſſage far advanced, the Miner endeavours to gain the Foot of the Breach, either by ſwimming, or by Means of a Raft. Being got there, he immediately hides himſelf under the Rubbiſh of the Breach, *&c.*

THE Gallery that is to be made in the dry Ditch, is to have the ſame Proportions: The Planks or Boards which are to cover the Sides, muſt be faſtened, within, on the Chandeliers, and the other Planks or Boards, forming the Ridge, are to be faſtened, above, on the Top. The Figure of the Chandeliers is repreſented in the Plate by *A:* They are to be placed at the Diſtance of nine Feet from each other, on the Bridge; or elſe, level with the Ground at the Bottom of the dry Ditch.

THE Letter *B* repreſents the Ridge, or Top of the Miner's Gallery for paſſing the Ditch.

C repreſents the Bridge, on which the Gallery is erected.

D the Water of the Ditch.

THE floating Bridge *A.* in the following Figure, is to be raiſed upon two Barrels of 20 Inches Diameter, and from two Feet to two Feet ſix Inches long: And theſe Barrels are to be very well ſecured with Iron Hoops, and to have Rings for faſtening them to the Joiſts, that are to be placed upon them.

THE better to carry on this Work, there ought to be Frames compoſed of three Joiſts of Fir, 12 Feet long, four Inches by three Inches in the clear, joined by three Croſs-pieces of nine Feet long, according to Figure *B.* At the End of each Joiſt is to be an Iron Hook, deſigned for faſtening the Joiſts and Croſs-pieces, at whoſe Extremities alſo there are to be Hooks and Rings for keeping the Frames together, when they chuſe to erect the Bridge. There are nine Barrels to be fixed under each Frame, three at each End, and three in the Middle; with Fir Planks nine Feet long, and one Inch thick above the Joiſts, to complete the Bridge.

For a Ditch 20 Toiſes broad, it is neceſſary to have ten Frames, each of which will weigh, at the moſt, 1100 Pounds, when furniſhed with Barrels and Planks. Eight Carts with four Horſes each, will be ſufficient to carry Bridge and Barrels, conſtructed as above, through all Roads.

Chests likewiſe may be uſed, made of four Boards, tacked upon four ſquare Pieces of the ſame ſort of Boards, each Piece one Foot ſquare; two of theſe are to form the two Ends, the other two, are to be placed at an equal Diſtance in the Middle; after which, for ſecuring the Whole, Iron-Plates or Hoops are to be diſpoſed in ſuch manner, as that one of them ſhall croſs the Top of the Cheſt juſt where the ſeveral ſquare Pieces of Wood are fixed; to the top of which Iron-Plates or Hoops, Rings are to be placed for faſtening the Cheſts to the Frames.

The length of theſe Cheſts is to be nine Feet; they muſt be well caulked to keep out the Water. There ſhould be three under each Frame, weighing ſomewhat more than the Barrels; but they are however, more portable.

A Bridge conſtructed after this manner, is excellent for paſſing a wet Ditch, or Rivulet, with Expedition.

The Miners Gallery muſt be ſituated on that ſide of the Bridge, which is next to the Flank, and it muſt be covered with Planks two Inches thick; the top, marked *E*, in the Figure of the Gallery, is likewiſe to be of the ſame thickneſs, to render it Proof againſt Muſquet-Shot; the other Side, marked *F*, is only covered with ſingle Planks, becauſe there is not the like Danger: As to the remaining Part of the Bridge, marked *C*, on the Side of the Gallery, it ought to be covered with Earth two Inches thick, to prevent its being burnt by the Enemy's Fire-Works.

This part *C*, will be very uſeful, for conveying by night, ſuch things, as Barrels, Faſcines, and Sand-Bags to fill-up the Ditch, while the Miner is carrying-on his Mines: Whilſt the Gallery conſtructed, as above, will ſerve to give the Miner, and his Workmen, a ſafe Paſſage.

Pontons might be of uſe for raiſing even a larger Bridge, but then they are by no means proper for a Gallery: Becauſe, ſhould the Enemy fire upon them never ſo little with Muſquet-Shot from the oppoſite Flank, or throw in Grenades, they would pierce through them, and ſink them with the Gallery itſelf; a damage, which could not be repaired without much Trouble, and a conſiderable loſs of Time.

The above Bridges therefore, are both lighter and ſafer for ſuch an Enterprize: Becauſe, being level with the Water, there is certainly leſs hold for the Muſquet-Shot and Grenades, than there can be in Pontons, or Wooden-Boats.

When the Gallery is advanced to the Wall, marked *I*, of the Face of the Baſtion, Half-Moon, or other Work, where they deſign to fix the Miner; the oppoſite Defences being demoliſhed, as before obſerved; if there ſhould yet remain any Space between the Gallery and Miner's Entrance, the Miner will there place two-inch Planks, obliquely, againſt the Wall, like a Shed, covered for ſecurity, with Skins or Tin, as the Gallery.

The Captain of the Miners being either inform'd by Spies, or gueſſing at the Thickneſs of the Wall, and that of the Earth about it, ſhall order it to be bored through, till they come to the Earth behind it. The Hole for the Miner, if poſſible, ought to be formed by the Beſieger's Cannon, before the Gallery is made.

THERE are ſeveral Places where the Miner may be fixed without a Gallery, particularly in dry Ditches: If the Earth prove eaſy to dig, a Sap is to be carried from the Counterſcarp to the foot of the Wall, which is to be mined; and this Sap, as it advances, is to be covered with double Faſcines, well bound together; which Faſcines alſo are to be covered with Earth, to prevent their being burned by the Enemy.

IF it is ſuſpected, that the Wall to be mined, is countermined: In this Caſe, the Beſiegers are to carry their Branches under the Countermine, that ſo the Chamber of their Mines may be under their Enemy's Countermines.

WALLS, which have Earth behind them, having been dug through, ſo as to form an Opening of four or five Feet both in Height and Breadth; the Captain of the Miners ſhall order Holes to be bored in the Earth, to the Left Hand, with an Augre of a proper Bigneſs and Length, to give him a better Opportunity of liſtening, on which Side it is, that the Beſieged may be carrying on their Countermines. If they ſhall find it is to the Right, it will be proper for them to open their Branch behind the Wall to the Left, and to make a conſiderable Noiſe to the Right, as a Deception to the Enemy: If the Enemy's be to the Left, they muſt then open theirs to the Right, for the Reaſon juſt given. If they hear nothing, they are to open their Branches on each Side, behind the Wall, for about 18 or 20 Feet; at the End of which, they muſt break into the back Part of the Wall two or three Feet, in Proportion to its Solidity, in order to make the Chamber, *C D*, to be ſunk two Feet below the Level of the other Branch, which had been opened, level with that at the Bottom of the dry Ditch.

In the wet Ditch alſo, the Wall is to be opened level with the Water; but here, the Branches are to aſcend, as it were, imperceptibly, by a Riſe of a Foot and an half, or two Feet, till you reach the Chambers themſelves; in ſuch ſort, that the Chamber, which is digged at the End of the Branches, may not be ſo deep as the Level of the Water. Theſe Chambers ought to be capable of receiving 4 or 500 lb. of Powder. The Miner at the ſame Time, ought to be careful to ſhore up the Top of the Branch with Planks, in Proportion as he digs out the Earth.

The Counterforts, marked 2, which are found at the Entrance, ſhould be equally bored at the Branch, whoſe Size is to be from three Feet, to three Feet ſix Inches in Breadth and Depth; where a ſmall Chamber, marked 8, is to be made, proper for admitting a twelve-inch Bomb on the Side of the Queüe of the Counterfort; which Shell is to be filled with Powder, ſo that it's Fuſe may have a Communication with the Sauciſſon, and continue burning till the Sauciſſon ſets Fire to the Mine.

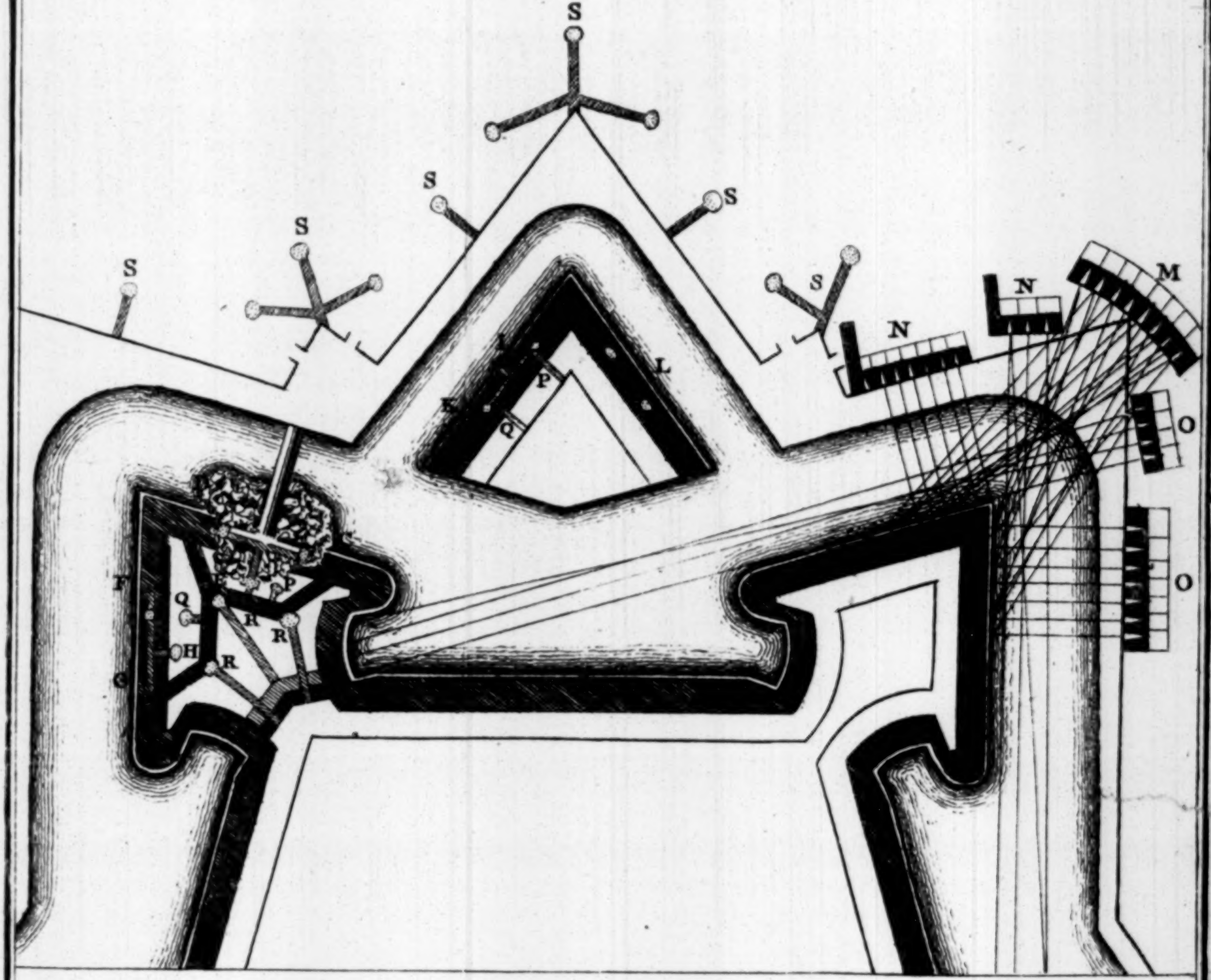
THE Shells placed in the Counterforts, as I have juſt now remarked, are of great Uſe to the Engineer, where a Wall is to be overturn'd and thrown into the Ditch; as alſo in facilitating the total Demolition of thoſe Queües of the Counterforts, which, by remaining in the Ground, are often obſerved to render the Breach much more difficult of Acceſs: Foraſmuch as the Remainder of theſe Queües of the Counterforts prevents the Earth from falling into the Ditch, and therefore obliges them to employ their Cannon, before they can properly level the Breach.

ONE Shell at each Counterfort, not only ſaves this Trouble, but likewiſe the Waſte of Time, which, in theſe Caſes, is always a Matter of the greateſt Conſequence.

AT the ſame Time that the Engineer opens the Branches, to the Right and Left, behind the Wall; that in the Middle, oppoſite the

Pl. 4

Page 62



Entrance of the Mine, is alſo to be opened; which muſt be carried directly forward into the Earth, for about 18 or 20 Feet every Way, conſtructed as thoſe above; having therefore a Chamber at the End of it, below the level of the Branch, ſufficient to contain 5 or 600 lb. of Powder, and ſometimes 1000 Pounds. This laſt Fourneau carried thus into the Earth, is of great Service for throwing the Remains of the Wall and Earth, between the other two Mines, into the Ditch; and alſo for levelling the Breach, by the vaſt Quantity of Earth, which this Mine will throw down, in caſe they are obliged to carry their Branches on one Side to avoid the Enemy's Countermines: After having advanced that Mine, which joins the Back of the Wall, 30 or 40 Feet forwards, a Chamber is made at it's Extremity, in the Wall *F*, as was before remarked.

THE ſecond Chamber, where it happens, that there is a Countermine on one Side, ſhall likewiſe be made, behind, in the ſame Wall, ſix Feet diſtant from the Entrance of the Branch, between the two Mines; for the Conſtruction of which ſecond Chamber, a Branch ſhall be carried into the Earth, ſo as to advance it 18 or 20 Feet forwards: At the End of which Branch, the Chamber itſelf is to be made for lodging the Powder. The utmoſt

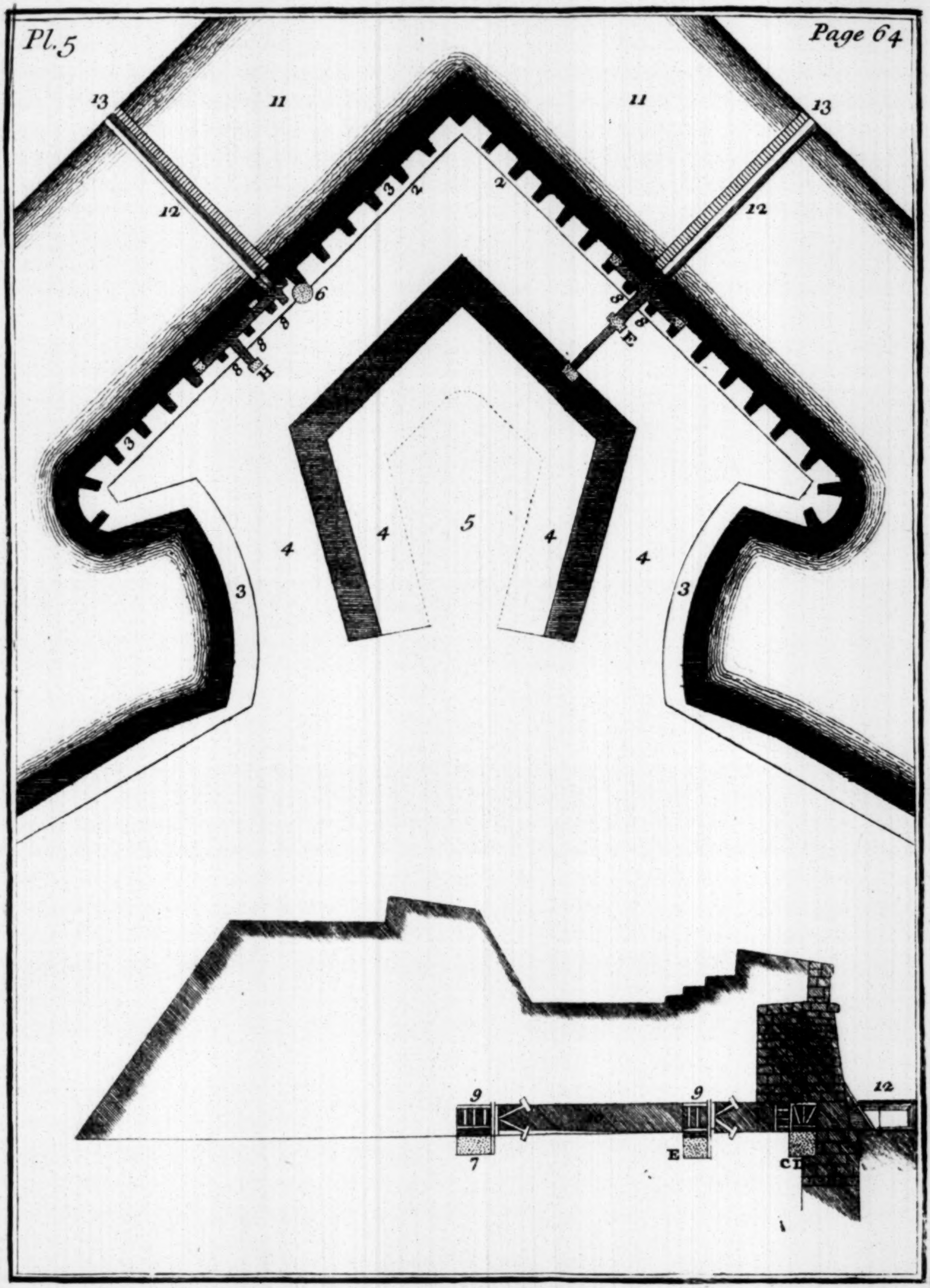
Care muſt be taken that all Branches thus carried under Ground, be extremely well ſhored up; becauſe, the Earth, will otherwiſe fall-in, and, by that Means, not only retard the Work, but actually ſmother the Miner. The Figures *C*, *D*, *E*, in the Plate repreſent the firſt Mines: Thoſe marked *F*, *G*, *H*, the ſecond Sort of Mines.

These two Sorts of Mines are excellently well contrived for the throwing down large Walls, and ſuch Ramparts as have ſuffered no Diminution in their Thickneſs.

When a Wall, in which a Breach is to be made, is known to have but little Earth behind it; the Miner muſt content himſelf with making Fourneaus in the back-part of the Wall; the Branches being conſtructed as before.

When there happens to be no Earth behind the Wall, the Branches muſt be advanced in the Middle of the ſolid Part of the Wall, 10 or 12 Feet, to the Right and Left; at the Extremity of which Branches a Chamber muſt be made, below the level, ſufficient to lodge 150, or, even 200 lb. of Powder, for the ſtrongeſt Walls; or elſe, a Branch muſt of itſelf be ſo form'd as to be capable of containing that Quantity of Powder. It is the Buſineſs of the Captain of the Miners, to judge of the Strength of the Wall by it's Height, and

Pl. 5



Obſervables in the opening it; and likewiſe what is to be the Size of the Breach, which the General requires.

EXPLANATION of the FIGURES.

1. *The Thickneſs of the Wall.*
2. *The Counterforts.*
3. *The Parapet.*
4. *The Rampart.*
5. *The Cavalier.*
6. *The Countermine.*
7. *The lengthening of the Mine to blow-up the Cavalier.*
8. *Counterforts mined.*
9. *The Props of the Mines.*
10. *The Opening of the Branches.*
11. *The Ditch.*
12. *The Bridge, and Profil of the Gallery on the Ditch, with the Miner's Plank, which ſhuts-up the Hole.*
13. *The Counterſcarp.*

THE Branches which are to be carried into the Body of a Wall, are not to exceed three Feet in Depth, and about two Feet ſix Inches in Width. This Sort of Mine is marked with the Letters *I*, *K*, *L*, and is of wonderful Service for blowing-up the ſtrongeſt Walls.

It is not always the great Quantity of Powder, that produces the greateſt Effects in Mines *; but their being well cloſed-up, and properly ſhored, as I ſhall hereafter demonſtrate. When the Powder exceeds in Quantity, it gives a too ſudden Vent to the Mine, ſuppoſing it is not cloſed-up in exact Proportion to it's Force and Quantity. Wherefore to aſſiſt the Miner † in proportioning the Chamber of his Mine exactly

---

[*] Whatever be the Quantity of Powder, wherewith a Mine is charged, it will produce no Effect if the Mine be not firmly cloſed; but will only blow in the Gallery, without raiſing the Earth above the Fourneau: While, on the other Hand, if the Charge be not duly proportioned, let the Mine be ever ſo well ſtopped, it will likewiſe prove ineffectual. Therefore, that a Mine may produce the deſired Effect, it is not only neceſſary, that it be charged with the Quantity of Powder requiſite; but alſo, that it's Gallery be carefully ſtopt, in ſuch ſort, that the Powder may meet with a greater Reſiſtance towards the Gallery, than in raiſing the Earth or Maſonry above the Fourneau.

[†] Since Powder acts with it's whole Force in the Chamber of a Mine, it is abſolutely neceſſary, that it be free from every Chaſm, or Vacuity; becauſe, where any thing of that Kind takes Place, it's dilating Force muſt needs act, immediately, upon the Earth ſurrounding ſuch Void.

To make the Fourneau of a proper Size, it is neceſſary we inform ourſelves, how many Pounds of Powder are required to occupy a cubic Foot. [Every Perſon knows that a Cube is a Solid, terminated by ſix equal Squares like a Die.] Experience has demonſtrated, as Mr. *de St. Remy*, here ſays, that eighty Pounds are the Standard in this Caſe. It follows therefore, that an hundred Pounds occupy 1 $\frac{1}{4}$; 140 Pound, 1 $\frac{1}{2}$; 160 Pound, 1 $\frac{3}{4}$, &c.

It

exactly to ſuch a Quantity of Powder, as he ſhall judge neceſſary to be lodged in it, for throwing down any intended Wall, and adjacent Earth; I ſhall here ſubjoin the Weight of a cubic Foot of Powder, which is, that it ought to be eighty Pounds; one Foot one Inch, Cube, will weigh an hundred Pounds; and one Foot, two Inches and 11-12th, an hundred and fifty Pounds; and two hundred Pounds of Powder will be one Foot five Inches, Cube.

It is, however, to be obſerved, that there are thoſe, who don't allow, that a cubic Foot contains 80 Pound of Powder; ſince it has been found by ſome, who have made particular Experiments of this Kind:

1ſt, That that the Powder being put lightly into a Veſſel of a foot Cube, contain'd only 60 Pd.—2 Oz.

2dly, That the ſame Powder being ſtrongly preſſed down into the Veſſel, it contained 95 Pd.—4 Oz: But this Weight may vary according to the Quantity of Saltpetre found in the Powder.

It is uſual to make the Chamber of the Mine of a cubic Figure; becauſe, as the Powder, in this Caſe, takes Fire in the Center, it more equally communicates itſelf to all Sides of the Fourneau. It might, for the ſame Reaſon, be made Spherical; but its Conſtruction would then be more difficult. Nevertheleſs, there are Perſons very ſkilful in the Science of Mining, who pretend, that they can make the Chamber in the Shape of a Cheſt, whoſe Altitude is to be leſs than its Length; becauſe the Mine would then make a greater Excavation, or a wider *Entonnoir*: [For it is by this Name, that they call the void Space, which a Mine leaves, after it has been ſprung.] But ſince Experience has not, as yet, ſufficiently confirm'd the Truth of this Aſſertion, we ſhall here ſpeak of the common Chamber only, that is to ſay, the Cubic. To

By obſerving the above Dimenſion, the Chamber of a Mine may be ſo made, as to contain, exactly, the aſſigned Quantity of Powder.

To render this ſtill more intelligible, we are to know, that one Pound of Powder occupies the Space of two Inches 10-12ths of a Cube, whoſe Side is a Square; which being thrice multiplied, gives 22 Inches 8-12ths for the whole Cube.

Wherefore to find what Part of this Cube 20 Pounds of Powder will occupy, multiply 22 Inches 8-12ths, (which contain one Pound,) by 20, and it will produce 453 cubic Inches, the Side of whoſe Cube will be 7 Inches 7-12ths. So

---

To make a Cube, which ſhall contain a determinate Quantity of Powder, for Example, one hundred Pounds; this is the Method:

A Cubic Foot contains 80 Pounds, conſequently, 100 Pounds, 1 Foot and ¼ in Space. I obſerve that this Quantity contains 2160 cubic Inches; therefore, to find the Baſe of a cubic Foot, I multiply 12 by 12, whoſe Product is 144; and to find the ſolid Contents, I multiply the Baſe by the Altitude, that is, 144 by 12, which gives 1728 cubic Inches: To this Quantity muſt be added ¼ for the Space occupied by 20 Pounds, which is 432, and this produces 2160 cubic Inches, for the whole Space ſought. It remains now, that we find the Side of a Cube, which may contain this Quantity, and this is found by extracting it's Cube-Root, which gives nearly, 13 Inches. Thus the Baſe of the Chamber of a Mine, which contains an 100

So that, from the preceding Dimenſions of Powder, it is eaſy to deduce the Proportions requiſite for the ſeveral Chambers of Mines.

---

100 Pounds of Powder, ought to be a Square, whoſe Side is 13 Inches, and it's Altitude 13 Inches likewiſe.

It is no difficult Matter, to conſtruct a Table for the Dimenſions of Chambers, for all the different Charges of Mines: Only obſerving, that the Chambers are to be about $\frac{1}{3}$ larger, to prevent their preſſing the Powder, and alſo with a View to their containing the Planks with which the Sides are generally covered, and the Straw whereon the Powder is laid, to prevent its contracting any Dampneſs.

We here therefore annex a Table of Marſhal *Vaubans*, extracted from his Treatiſe on *the Attack of Places*, which ſhews, at one View, the Side of the Chamber of a Mine, with reſpect to the Quantity of Powder it ought to contain; regard alſo being had to the Planks and Straw that are to be placed in it for keeping the Powder dry.

A Table of the Charges of Mines, according to Marſhal de Vauban, *wherein the Dimenſions of the Chambers of Mines are aſſigned, with reſpect to the Quantity of Powder they are to contain, together with the Height of the Ramparts, above the Chambers.*

Height of the Rampart above the Chambers.	*Depth of the Galleries to the Chambers.*	*Meaſure of the Chambers in common Feet and Inches.*		*Quantity of Powder requiſite.*
Feet	Feet	Ft.	Inc.	Pounds
10	5	0	7	10
12	6	0	8	18
14	7	0	10	28
16	8	0	11	42
18	9	1	1	60
20	10	1	2	82
22	11	1	3	109
24	12	1	4	142
26	13	1	5	180
28	14	1	7	226
30	15	1	9	277
32	16	1	10	336
34	17	1	11	403
36	18	2	1	479
38	19	2	2	564
40	20	2	4	617
42	21	2	5	761
44	22	2	6	875
46	23	2	8	1000
48	24	2	9	1136
50	25	2	10	1294
52	26	3	0	1444
54	27	3	1	1617
56	28	3	3	1803
58	29	3	4	2004
60	30	3	6	2218
62	31	3	7	2447
64	32	3	8	2692
66	33	3	10	2952
68	34	3	11	3229
70	35	4	0	3522
72	36	4	2	3833
74	37	4	3	4161
76	38	4	4	4510
78	39	4	6	4873
80	40	4	7	5258

General Rules to be obſerved, in order to charge Mines, and Fourneaus, properly.

IF, when the Mines are conſtructed, Water ſhould be found at the Bottom of the Chamber, it will be neceſſary to lay Planks there, on which the Powder is to be placed either in Sacks, or Barrels of an hundred Pounds each.

DUE Care having been taken to leave no Vacuity in the Chamber, and that the whole of it be well filled-up with Forage; the next thing, is, to place the Saucifſon in ſuch Manner, that it may have a clear Paſſage to the Powder; obſerving that this Sauciſſon in it's Exit from the Chamber, be laid in a * wooden Trough through all the Branches.

THE Uſe of this *Auget* is to prevent the Sauciſſon's being preſſed by the Materials, which fill-up the Branches, and therefore to preſerve it from being extinguiſhed before it has fired the Mine; an Accident, to which it would certainly be expoſed, were it not thus incloſed in the Auget; the Size of which is to be three Inches Square. As to the Sauciſſon, which is to be made of coarſe Cloth, it ought to be juſt one Inch Diameter, and as long as the Occaſion requires: The Cloth muſt be ſewed double through

---

* This Trough is termed *Auget*.

through it's whole Length, and then filled with Powder by means of a Funnel.

When the Powder is once placed in the Chamber of the Mine, Planks are to be laid above for covering it; and then, other Planks, croſswiſe, above theſe: This being done, another Plank, expreſſly ſhaped for this Uſe, is to be placed underneath the Top of the Chamber; then, between this Plank, and thoſe, which cover the Powder, ſeveral Props are to be uſed for ſhoring-up this Plank at the Top; ſome of which Props are to incline towards the Outſide of the Wall, and others of them towards it's Inſide: While the different Vacuities, between theſe Props, are to be filled-up with Earth, Dung, Brick, and rough Stones. Afterwards, Planks are to be placed at the Entrance of the Chamber, with one acroſs the Top of them, on which Croſs-plank, they are to ſet-up three ſtrong Props, the one End of which Props, is to reſt againſt another Plank, which ſhall be placed againſt the Side of the Earth in the Branch; all theſe Props are to be thoroughly faſtened, by Wedges, between the Planks: After this, the whole Branch ſhall be filled-up to it's very Entrance with the Materials aforementioned.

The Chamber of the Mine, which is carried into the Ground, muſt be charged like that in the Wall; except only, that the Props, which are above the Planks of the Chamber, are to be ſhored, the one perpendicular, and the other two inclining to the Right and Left; the Vacancies being every where carefully cloſed up. After this, the Entrance of the Chamber is to be ſtopped-up with ſtrong Boards, the Extremities of which are to be ſunk into the Ground; while another Plank is to be laid croſs-ways, a-top, on which three Props are to be ſhored, the centre one being to buttreſs againſt one or two Pickets, placed either above, or level with the Branch; and the other two againſt the Planks, which are on the Sides of the Branch, that is ſunk into the Ground: Then the Branch is to be filled-up to its Entrance; Care being always taken, that the Materials don't preſs the Auget, which contains the Sauciſſon.

THE SAUCISSONS, which paſs through the ſide Branches, muſt be exactly of the ſame Length with that in the Middle, where they are to unite. The Part, which reaches beyond the Entrance of the Mine, is that, which conveys the Fire to the other three. The Sauciſſons being thus of an equal Length, and placed as above directed, it is impoſſible, that the three Mines ſhould fail of ſpringing together, which muſt, of Neceſſity, produce a far greater Effect,

fect, than if they had ſprang ſeparately, one after the other. Beſides, it is dangerous to have them ſpring in that Manner; becauſe it may happen, that the firſt Mines ſpringing before the reſt, may either give Air to them, or choak up the Sauciſſons by their Shock; in conſequence of which, the grand Effect originally propoſed will be defeated, and infinite Diſadvantage ariſe to the Beſiegers, by their Loſs of Time, as it happened at ———. But when the three Mines, take Fire at the ſame Inſtant, as muſt be the Caſe, where the Sauciſſons are found of an equal Length, they will, conſequently, make a Breach of 10 or 12 Toiſes wide, and at the ſame Time, very deep, by which Means, above half of the Ditch will be filled-up, provided the ſeveral Steps, as here taught, be punctually obſerved.

It is proper, that the Captain of the Miners, take frequent Opportunities of acquainting the General with the Progreſs of his Mines; and, particularly, of the Time, wherein, he apprehends they will be finiſhed: That ſo the General may order his Troops to hold themſelves in Readineſs in the Places of Arms, and in their Trenches, for giving the Aſſault immediately after the Mine is ſprang, that by this Diſpatch, the Enemy may have no Time to recover their Conſternation.

It is the Engineer's Buſineſs to ſee that Banquets be made at the Head of the Trench, for the Beſiegers ſtepping over the Front, and that Sorties may ſally out from all Parts to the Breach. In the Draught of the Mines of the ſecond Figure, the Letters *C*, *D*, *E*, and *F*, *G*, *H*, as alſo *I*, *K*, *L*, point out, in the Branches, the Courſe which the Sauciſſon ought to take, ſo as to communicate the Fire equally to the ſeveral Chambers of the Mines at one and the ſame Time.

Of Countermines, and Fougaſſes, which the Beſieged make to annoy the Beſiegers.

HAVING already ſufficiently treated of the Conſtruction of Mines, which are deſigned to make large Breaches in a Place beſieged; I come now to ſhew, what is to be obſerved with regard to Countermines, and how to conſtruct Fougaſſes, in order to blow-up ſuch Works and Intrenchments, as the Beſieged are ſometimes forced to abandon to the Enemy.

If the Wall of a Baſtion, or any other Work, which the Enemy attacks, with an Intent to fix his Miner in that particular Place, happen to be countermined, the Ditches at the ſame Time being full of Water, whether running or ſtagnated, but ſuch as will neither admit of being drained off, nor of having it's Courſe turned; the Beſieged, in this Caſe, have nothing to fear from their fixing the Miner; becauſe the Water will prevent his making a Mine under the Countermine of the Wall, as he might have done had it been a dry Ditch. Beſides, ſhould he attempt to break into the Wall, level with the Water, he would then meet with the Countermine, where it would be very eaſy to kill him, and conſequently, prevent the Progreſs of his Mine.

THE Enemy being appriſed of this Incident, will immediately have Recourſe to their Cannon to batter in Breach; tho' that is far from being ſo ready a Thing, as the Mine. However, that it may be compleated in the Space of 48 Hours at the ſalient Angle of the Baſtion, I would have the Batteries conſtructed, like thoſe, marked *M*, *N*, *O*, Plate 4. The firſt Battery, *M*, conſiſting of eight Pieces of Cannon, muſt be planted directly oppoſite the ſalient Angle of the Baſtion, to play, from behind, upon a third, or one half of it's Faces. The other Batteries, *N*, *O*, muſt be conſtructed upon the Faces of the Covert-Way, to play likewiſe upon the Faces of the Baſtion, croſſing the firſt Battery, fired at the ſame Elevation.

ALL the Shot from the Batteries being fired level at the Angle, as I juſt now ſaid, will ſoon undermine the Wall, and throw down the Angle with one third of the Faces into the Ditch, the Rubbiſh of which will fill-up a great Part of it; while there will be a Breach made ſufficient for 30 Men to enter a-breaſt.

THIS is termed battering a Wall *en chapelet*; or firing a-croſs at the ſame Elevation, and at a level with the Water of the Ditch or Counterſcarp. A Breach was made after this Manner at the Citadel of —— in the Baſtion oppoſite the Town, though there was no Water in the Ditch, nor the Wall countermined. The Batteries on the Face of the Covert-Way may be lengthened on the Side of the Salient-Angle, ſo as to mount three Pieces of Cannon, for playing upon the Defences of the oppoſite Flanks.

THE Beſieged will endeavour to diſcover that Part of the Baſtion, where the Beſiegers carry on their Mines for making a Breach; and this they may do with Advantage, either by laying their Ear cloſe to the Ground and liſtening attentively; or elſe, by placing a Drum on the Spot, under which they imagine the Enemy to be at work: For if the String of the Drum ſtrike upon the Parchment, it is certain, the Enemy's Miner Works in that Place; and therefore that they may dig the Ground to countermine him with good Aſſurance. If they ſhould meet the Branch of the Mine by ſounding: In that Caſe, it will be neceſſary that boiling Water, or even what is cold only, be continually thrown-down by the Hole, in order to precipitate the Earth into the Branch.

WHEN the Branch is once found, the Beſieged may eaſily prevent the Progreſs of the Mine, either by killing the Miners with Pikes, or other Weapons of that Sort; or elſe, by throwing-in a Quantity of Grenades, and Fire-works, which muſt needs ſtifle them.

As there are ſeveral Miners in an Army, when it lays Siege to a Place, it will be very difficult for the Beſieged to prevent them in advancing Mines, in one Part or another, for forming a Breach; but even then, the Annoyance, which the Beſieged may give the Enemy's Miners by their Countermines, will afford them Opportunities for making Intrenchments upon the Baſtion, or other of the attacked Works, under which they may likewiſe make Fougaſſes to blow-up the Enemy, when they are intrench'd on the Breach. This Sort of Fougaſſe is mark'd with the Letters *P*, *Q*, *R*; in the ſecond Figure.

SEVERAL Retrenchments may be made at proper Diſtances from each other on the attacked Work, with Fougaſſes underneath; to each of which the Beſieged may paſs by Means of theſe Retrenchments, when driven from any one of their Works; and, conſequently, ſecure to themſelves an Opportunity of ſetting Fire to the Sauciſſons of the ſeveral Fougaſſes, which are lodged under theſe Retrenchments.

By this Method a Baſtion may be defended Inch by Inch, even to the Intrenchments of the Gorge; and there they may capitulate.

Fougasses are very ſerviceable to blow-up all Kinds of fortified Works, after the Beſiegers have made themſelves Maſters of them. They are conſtructed at the Salient-Angles under the Glacis of a Covert-Way, marked *S*; with a Deſign to blow-up the Enemy, when they advance to attack it.

In Places, which are ſtrongly fortified, the Branches and Chambers of the Fougaſſes are prepared under Ground, ready for being Charged, when Occaſion requires: They are charged, and cloſed-up, in the ſame Nature as Mines. Four hundred Pounds of Powder is ſufficient to demoliſh all the Works, the Enemy may have raiſed in a detached Redoubt.

An hundred Pounds of Powder will likewiſe be ſufficient for each Chamber of the Fougaſſes, conſtructed under the Glacis and Intrenchments.

What now remains is to give ſome Account of the proper Tools for mining, and the Perſons to be employed in that Service.

The

The Miners Tools are:

A SPADE guarded at the Edge with an Iron-Plate, the Handle of which is to be a Foot long. This ſerves to throw aſide the Rubbiſh of the Branch, as the Miner advances.

A SECOND Spade, whoſe Handle is to be one Foot ſix Inches long: This ſerves another Perſon, who ſtands behind, to clear away the Rubbiſh, when the Branches are deep, by throwing it into a Wheel-barrow, framed on four Wheels.

THIS Wheel-barrow holds about a Cubic Foot of Earth: It has a Rope faſtened to the back Part of it, by which a Man draws it up to empty the Rubbiſh, and another Rope forwards, by which it is drawn down again.

THESE two Men are wholly employed in emptying the Branch, and muſt be relieved every Hour, juſt as the Miner is, by ſome other Hands.

THE Miner has alſo a Stone-Axe; a Pick-Axe; an Hand-Leaver; and two Chiſſels, the one large, the other ſmall.

ALL the Tools ſhould be well ſteeled at the Edges, to give them the greater Force for breaking the Maſonry.

When the Miner is under Ground, he muſt be provided with a Pick-Axe, Mattock, and a Pic, whoſe Helve ought to be one Foot ſix Inches long.

Each Branch ought to have a complete Set of Tools; and another Set in reſerve leſt any of them ſhould break.

There muſt likewiſe be a Carpenter in each Branch, to ſhore-up, as the Miner advances; and two others, who are to ſhape the Wood neceſſary in this Caſe, and, at laſt, to cloſe-up the Chamber.

These two laſt alternately relieve the other, who works in the Branch; not on account of his hard Labour, but becauſe it is requiſite he ſhould take freſh Air.

Having then ſpoken to the ſeveral Things proper to be obſerved for the Conſtruction of Mines and Fougaſſes, employed in the Attack and Defence of Places; we now proceed to exhibit the Method for ſapping the Walls of a Place, which is to be razed: To which we ſhall ſubjoin the Manner of placing thoſe Fourneaus, which are deſigned to throw down Towers, whether intire, or partial; and this, with ſuch Precaution, that they may neither damage the Houſes in the Town, nor choak up the Rivers, which run near them.

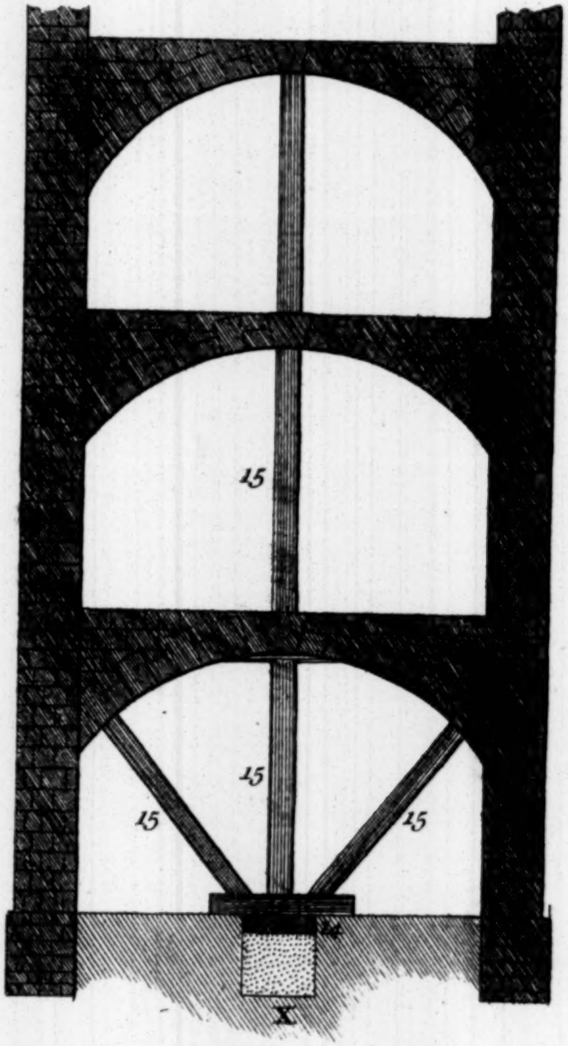
It is no difficult Matter to make Saps, and what Fourneaus we pleaſe for razing a Place, where we have nothing to fear from the Enemy; becauſe in this Caſe, we have the Advantage of working by every Method, without the Neceſſity of being under Covert.

We have then to obſerve, that, when it is once reſolved to raze the Walls of a Place, if it be an antique, perpendicular Wall, it muſt be ſapped outwards, and ſhored with ſtrong Firr Planks, as they advance the Sap, from the Level three or four Feet, all along the Curtains, between the Towers: They are to carry the Sap into the ſolid Part of the Wall, to the half, or two thirds, of it's Thickneſs. As to taking away the Props and thereby throwing down the Wall, there are ſeveral different Methods.

The firſt, is that of binding Faggots to the Props, and then ſetting Fire to them.

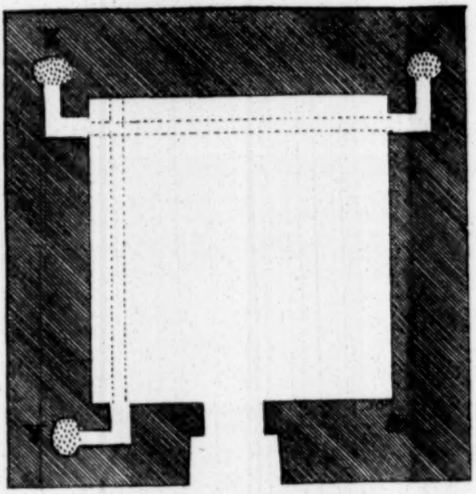
The ſecond, is to bore an Hole at the Bottom of the Prop, and put an Ounce of Powder into it, and ſtop it with Paper, or Flax: After this, another Hole is to be bored, through the Prop, tranſverſely, with a ſmall Augre, near the other; through which a Match is to be put for conveying Fire to the Powder: The like is to be done to each Prop, and a Train of Powder laid, which may communicate the Fire from one

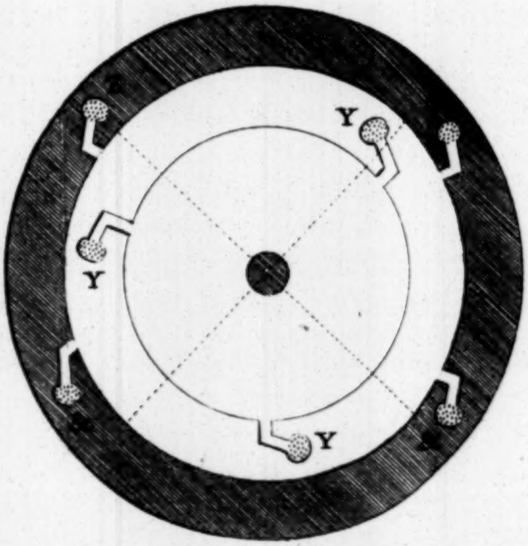
Pl. 6



Pl. 7

Page 82





one to the other. The Props thus falling, the Wall muſt of Neceſſity fall with them.

THE third Method, and in my Opinion the beſt, coſts neither Powder nor Fagots. Let there be only 24 Ropes provided, and let one End of theſe ſeveral Ropes be tied round the Bottom of each Prop; then let five or ſix Men, taking hold of the other End of each of theſe Ropes, be ordered to pull them, all together, by a ſudden Jerk; the Props, by this Means, being abſolutely diſplaced, the Wall, now deprived of every Support, muſt of courſe, immediately tumble. The ſame Method may likewiſe be uſed, where ſmall Towers are to be thrown down.

THE Walls of a Fortification which ſlope, cannot be ſapped, in the Manner above; but muſt be mined like thoſe, of the ſecond Figure, marked *I*, *K*, *L*.

WHEN they would intirely demoliſh round, and ſquare Towers, which have very thick Maſonry, and two or three ſtrong Arches; a Chamber, or Well, muſt be ſunk, in the Middle, at the Bottom of the Tower: The Figure of this Chamber is marked in the following Plate by *X*; it is to be three Feet deep, and as much in Diameter, in which you are to lodge from 300 lb. of Powder to 400 lb. if the Tower be five or ſix Toiſes Diameter, and very thick.

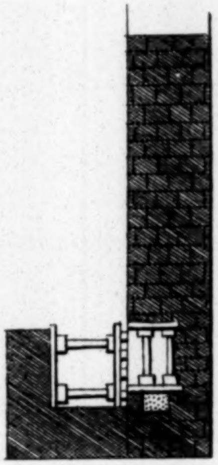
If there happen to be a Vacuity above the Powder, it is to be filled-up with Forage, or old Rags, level with the Bottom of the Tower; over which ſtrong Planks are to be laid, and others, again, acroſs theſe at the Top, on which you are likewiſe to place five or ſix Props of ſix Inches Diameter each, one of which is to be erected on the Planks in the Middle of the Well, butting againſt the Key-Stone of the Vault, upon one End of a Plank which is between two others; the remaining four Props are likewiſe to be placed on the other Planks at the Bottom round the center Prop, which are to bear, at equal Diſtances, againſt the Spring of the Arch, for ſupporting the other Parts of the Tower.

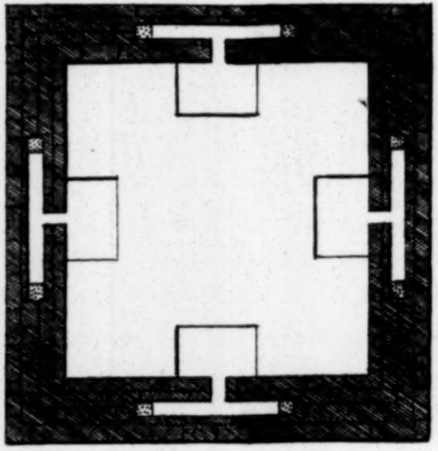
The Figure Plate 6, *repreſents the Profil of a Tower with three Arches, which may be intirely demoliſhed by ſhoring the Well, or Chamber*, X, *as it is marked by the Figures* 14 *and* 15.

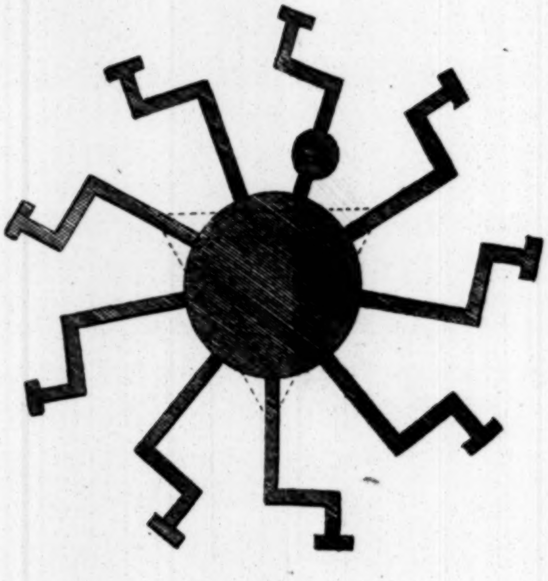
For ſtrong Towers that are not arched, Fourneaus are made in the ſolid Part of the Wall, at three different Places, as at *Y*, dug into the Foundation of the Wall, and capable of containing 50 or 60 Pounds of Powder each, ſeverally charged and ſhored as above directed.

When only the exterior half of the Tower is to be demoliſhed, on account of the adjoining Houſes; two Fourneaus are to be made

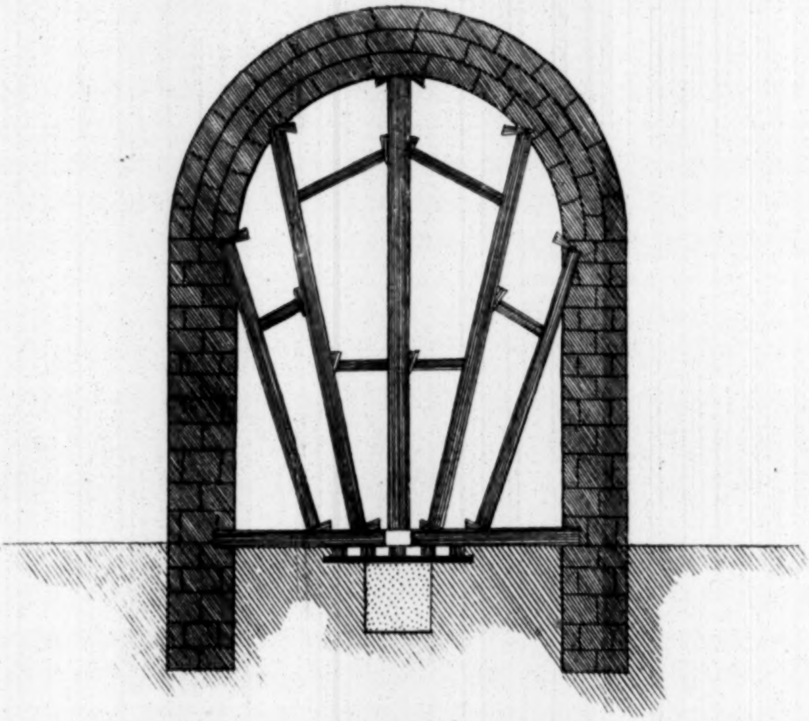
Another Method to blow up a round and square Tower.

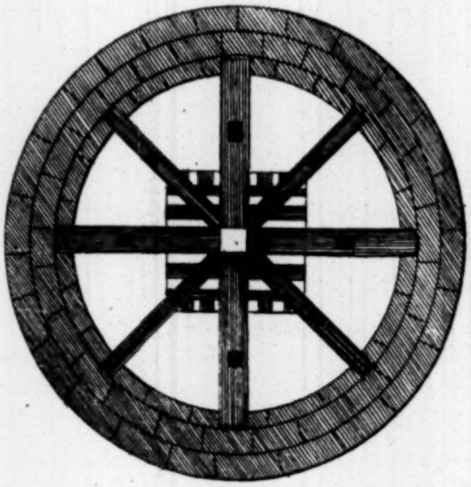






Pl. 9 *Page 84*





at the Diſtance of one third of the Circumference of the round Tower, and at the two Angles, oppoſite the Field, in the ſquare Tower; by which Means, one half of either will remain. If, on the contrary, they are diſpoſed to preſerve that Moiety of the Tower which is towards the Field, with a View to prevent it's filling-up a River; it will then be proper to obſerve the ſame Method in regard to the interior Parts of the Tower. The Fourneaus for preſerving the interior Half of a Tower are marked by *Z*, and thoſe for preſerving the exterior by &.

The upper Figure in Plate 7 repreſents the Plan of a ſquare Tower. When only the Front is to be blown-up, the Mines are made as Z; *and and when only the Part marked* & *is left, the Mine* Y *is added. Below is the Plan of a round Tower arched.*

For common Towers, that are only floored with Wood about ſix or ſeven Feet thick; the Fourneaus marked *Y* are of excellent Uſe for blowing-up the whole Tower, which may be done with 50 or 60lb. of Powder for each Fourneau.

The ſecond Figure Plate 9, repreſents the Manner of propping an Arch, over a Fourneau, for blowing it up.

THE preceding Memoirs on the Subject of Mines, are founded on very accurate Experiments, and may be conſidered, as ſufficient of themſelves to inform any Perſon in the Art of Mining: Neverthele ſs, as I would omit nothing, that might be ſerviceable to this great End, it may not be improper to inlarge this Chapter with another Tract, which may ſerve to inſtruct Beginners, in the firſt Principles of this Science, and lead them into the practical Part of Mining. The principal Memoirs on this Subject were communicated to me by Mr. *De la Motte*, Chief Commiſſary; whoſe Genius and great Merit, had gained him Eſteem in the Corps, not for his Skill in Mines only, but alſo for his conſummate Knowledge in the ſeveral other Branches of Artillery, of which his Lectures, delivered as Brigadier of the Schools eſtabliſhed in the Year 1680, give demonſtrative Proof.

THE Science of Mines, Fourneaus, Fougaſſes, and ſuch Countermines as are practiſed in Sieges, whether for the Defence, or Attack, of Places, is abſolutely requiſite for an Artillery Officer; as well to furniſh him with proper Abilities for conſtructing theſe ſeveral Works, as to inform him in the Manner of uſing them to the beſt Advantage, when they are conſtructed.

It may then be ſaid, that, ſince this famous Invention of Mining, there is no Place any longer impregnable: Becauſe the Beſiegers, working under the Beſieged, make themſelves as much Maſters of the Souterrains, as the Beſieged are of the upper Parts. It is for this Reaſon, that when it is determined to countermine a Place, the Countermines are to be advanced as low as poſſible; that ſo the Beſieged may remain Maſters both of the upper and lower Parts, by making them one Foot higher than the level of the Water. Not that I would be underſtood to mean, that the Countermines, which are conſtructed in a Work, ought to be thus low; becauſe by this Means, in ſpringing your Fourneau, which ſhould not be overcharged, you would throw your Baſtion, or other Work, into the Ditch, which is the very Thing the Enemy want, as it happened at *M*———.

It has been hitherto thought, that, by a particular Poſition of the Chambers, it was poſſible to throw the Earth and Rubbiſh, on either Side, as might be moſt convenient, where the Ground was level. This, indeed, is true with reſpect to a Bank:

But the Experiments, which Mr. *de* —— made at *Tournay*, in 1686, by the King's Command, have undeceived us in this Matter. Reaſon itſelf tells us, that the Powder cannot but act on the weakeſt Side; and ſince the Perpendicular drawn from the Top, is ſhorter than the other Lines, through which the Effect of the Powder muſt act to throw it to the right or left; it follows, that the Exploſion will be perpendicular, and not oblique: The Reſult of which is, that the particular Poſition of a Chamber, on a level Ground, will be, here, of no Conſequence.

MANY Perſons imagine, that the greater the Charge of a Fourneau is, the greater alſo will be the Effect it produces *. It is indeed, certain, that the Earth is thrown higher; that the Pit

---

* THERE is nothing more natural, than this Concluſion. Yet the Experiments here mentioned ſeem to demonſtrate the contrary, though all of them did not ſucceed alike. They were made at *La Fere* in 1729, to prove, that the greater the Charge of a Mine was, the greater would be the Excavation. They are related by Mr. *Le Blond* in his Treatiſe of Artillery, in the following Manner.

" AT LA FERE, in 1729, ſeven Galleries were made " in a Soil of the ſame Nature or Conſiſtence, and upon " the ſame Plane or Level. They terminated at Bottom " in a Pit ten Feet deep, ſo that all of them had *the Line* " *of leaſt Reſiſtance* ten Feet: For ſo they term that Line " which expreſſes the leaſt Height above the Fourneau. " The firſt Mine was charged with 120 Pd. of Powder; " the ſecond, with 160; the third, with 200; the " fourth, with 240; the fifth, with 280; the ſixth, " with 320; and the ſeventh, with 360. Theſe Mines " being ſprang, the Diameter of the upper Baſe of *the* " *Entonnoir*

Pit is made ſomewhat deeper, in the Middle; and that the Earth is ſpread farther, when there is too great a Quantity of Powder employed: But

---

“ *Entonnoir* of the firſt was found to be $22\frac{2}{3}$ Feet; of “ the ſecond, 26; of the third, 29; of the fourth, $31\frac{1}{4}$; “ of the fifth, $33\frac{1}{2}$; of the ſixth, 36; and of the ſeventh, “ $38\frac{1}{2}$.

THESE Experiments abſolutely confute thoſe made at *Tournay*, on the ſame Account; and therefore oblige us to conclude, that the preſent were apparently made in ſtony Soils, where the Powder could not act ſo freely as in the Soil at *Tournay*. However, it ſtill remains a controverted Point among Miners.

“ IT is a Problem with Miners, ſays Mr. *Bigot de* “ *Morogues*, Whether a Mine, charged with a vaſt Quan-“ tity of Powder, only cauſes an Entonnoir reſembling a “ Pit; or whether, notwithſtanding the Prepoſſeſſion on “ that Side, it makes an Excavation, whoſe Diameter “ greatly exceeds double the Line of leaſt Reſiſtance. “ Reaſon recommends, Theory demonſtrates, Experi-“ ence confirms the contrary Opinions, in the Judgment “ of their ſeveral Advocates.”

MR. DU LACQ agrees with Mr. *de Morogues*; and, indeed, both Experience and Reaſon ſeem to favour their Sentiments.

“ THE antient Miners, ſays Mr. *Du Lacq*, in his “ Treatiſe on the Mechaniſm of Artillery, imagined, that “ the Radii of the Excavations could never exceed the “ Line of leaſt Reſiſtance, whatever were the Charge; “ but Practice and Theory equally concur to refute this “ Opinion: Becauſe, if the Charge of a Fourneau be “ augmented, without ſinking it deeper, it is evident, “ that the Line of leaſt Reſiſtance, correſponding to this “ Charge, would have produced a greater Effect, even on “ their own Confeſſion. Let us then ſuppoſe, ſays this “ Author, that the Radius of the firſt Fourneau is equal “ to the Line of leaſt Reſiſtance; it is alſo ſtill clear, “ that

But all this is ſo far from being of any Advantage, that it is, in fact, a real Prejudice; becauſe, by this Means, the Enemy will have a better Opportunity for lodging themſelves on the Rubbiſh.

Mr. *de* ——— has given us Tables for the charging of Mines.—Firſt, it is proper you ſhould know the exact Height of Earth above you: For this being known, we are certain that a Solid, reſembling the Fruſtum of an inverted Cone, has it's upper Diameter double the Depth of the Pit, and its lower Diameter * equal to it.

" that if the ſecond Charge be laid deeper, ſo that each " correſponding Line of leaſt Reſiſtance be exactly pro" portioned to its Charge, the Radius of the Entonnoir, " which had contained this ſecond Charge, will exceed " that, which had been given to the former; ſince this " Radius will be equal to its Line of leaſt Reſiſtance, " which is apparently larger. Let us now put this ſecond " Charge into the firſt Mine, it's equiponderating Force " will be the ſame; therefore, having a greater Radius, " it ought likewiſe to produce a wider Entonnoir."

* The Experiments made at *La Fere* have demonſtrated, that the Diameter of the lower Baſe of a Mine is not equal to its Line of leaſt Reſiſtance, as has been aſſerted in the preſent Memoir. " This Diameter has " been found much leſs in Mines, whoſe Lines of leaſt " Reſiſtance were ten Feet. Among others, particularly, " in a Mine whoſe Line of leaſt Reſiſtance was ten Feet, " and which was charged with 1000 Pound of Powder, " inſtead of 93 Pound, it's proper Charge, the Diameter " of its lower Baſe was found to be only five Feet."

THE Solid Contents of this being meaſured, the Charge, requiſite to raiſe ſo many cubic Toiſes of each Soil will be readily known.

ALL Soils are reducible to theſe four, namely,

1. Hard Gravel.
2. Potters Earth.
3. Looſe Earth, or Sand.
4. All Kinds of Maſonry.

LET a Hole be made in the Earth equal to a cubic Foot, weigh the whole taken out of it; hence you will find the Weight of a cubic Foot of that Soil, and conſequently, of a cubic Toiſe.

TO raiſe a cubic Toiſe of hard Gravel, in firm Ground: it requires at leaſt, eleven Pounds of Powder: A cubic Foot of this Soil weighs 124 Pounds.

To raiſe a cubic Toiſe of Potter's Earth, in firm Ground, will require at the leaſt 15 Pounds of Powder: A cubic Foot of this Soil weighs 135 Pounds.

To raiſe a cubic Toiſe of looſe Earth, or Dry-Sand, 9 Pounds of Powder are neceſſary: A Cubic Toiſe of this Soil weighs 95 Pounds, 5 Ounces.

To raiſe a cubic Toiſe of Maſonry above Ground, 20 Pounds; but, if it be under Ground, 40 Pounds are requiſite.

It muſt be obſerved, that the greater the Charge of your Mine is, the leſs Exactneſs will be required in the Number of Toiſes; becauſe the Powder, when united, produces a far greater Effect, than in ſeparate Charges: And on the contrary, when the Powder is divided into ſeveral Lodgments, you are to ſuppoſe the Number of Toiſes increaſed about one Fourth, the better to proportion the Powder.

If there happen to be a greater Weight in one Place, than there is in another; the Charge in this Caſe, ought to be proportionally augmented, as was done at the Tower of *Reme*. It had different Heights; yet, the four Fourneaus were ſo exactly charged, as to blow-up the whole Tower, 12 Feet into the Air, without ſeparating it's Parts; afterwards it fell to Pieces.

Care muſt be taken, that you do not fall into the Error of ſome unſkilful Miners, who ſay: That if ten Pounds of Powder be neceſſary to raiſe one Toiſe, two Toiſes will require twenty; whereas the Weight of the one being octuple that of the other, it muſt of Conſequence require eighty Pounds.

Working theſe two Operations in Numbers, the above Miners ſay:

	T.	Pds.	T.	Pds.
If	1	10	2	20

It ought however to ſtand thus:

	T.	Pds.	T.	Pds.
If	1	10	2	80

Now the Obſervations exhibited above, deſigned to ſerve as a Baſis for the adjuſting the Charge of Mines, not being perfectly correct, as we have ſeen in the preceding Notes; it follows, that the Calculation which takes it's Riſe from them cannot be ſo throughly accurate as we could wiſh: Not but it muſt, at the ſame Time, be acknowledged, that it is extremely difficult to advance any thing abſolutely exact on the preſent Subject: Becauſe, to gain this Iſſue, the Figure of the Solid to be raiſed muſt be preciſely determined. But this Figure cannot be aſcertained except in ſuch Soils as are *abſolutely* homogeneous, which, it is certain, are ſcarcely ever to be met with. Proportionally therefore, as the Soil is found denſer on one Side than on the other; and, again, of greater or leſs Tenacity: So will the Figure of the Entonnoir certainly vary, and it is eaſy to perceive, that, on this Principle, it may vary *ad infinitum*. Nevertheleſs, as this is a Point, which reſpects the practical Part only, and not a Matter of geometrical Preciſion; theſe Solids will not remarkably vary their Figure in Soils *nearly* homogeneous: And therefore, whatever is determined with regard to one Soil, may ſerve as a Rule for all that are *nearly* ſimilar.

THE CALCULATION of Mines has hitherto been built upon an Hypotheſis, as we have ſhewn, that the Entonnoir of a Mine is the Fruſtum of an inverted Cone, whoſe Altitude is equal to the Radius of the Excavation of the Mine, and the Diameter of it's leſſer Baſe equal to the Line of leaſt Reſiſtance: And, notwithſtanding theſe Suppoſitions are not quite exact, yet the Calculation of Mines deduced from them, has proved ſucceſsful in Practice; for which Reaſon this ſame Calculation ought to be followed, till a better, and more ſimple Method, be found out; one, that ſhall be more conformable to the Theory of Mines, and confirmed by a Series of repeated Experiments. Practice, in theſe Things, ought always to have the Preference to the moſt refined Speculations, where they are found diſſonant to it. It is a long Time ſince Mr. *Belidor* promiſed a Treatiſe on the Theory of Mines; and it were greatly to be wiſhed, that he would ſoon oblige the World in this Particular. The ſingular Attention, which this Gentleman has given to the Theory of Gunpowder, has cauſed great Expectations from this other Work. *We may then, ſays* Mr. *Du Lacq, reaſonably hope, to gain an intire Certainty on this Subject.*

INSTEAD of the Fruſtum of a Cone, formed by the Excavation of a Mine, Mr. *De Valliere*, Lieutenant-General of his Majeſty's Forces, and Inſpector-General of the Artillery-Schools, diſcovered, that the Entonnoir of a Mine was a *Paraboloid*; a Solid generated by the Rotation of a Semi-Parabola about its Axis; as will appear from a Diſſertation of this celebrated Writer, deſigned to make a Part of this Treatiſe. But as the Meaſure of a Paraboloid is more intricate than that of the Fruſtnm of a Cone; and their Difference in Practice is very inconſiderable, it is Reaſon ſufficient, why we ſhould adhere to the latter. However, as the Meaſure of the Paraboloid is certainly more exact, we ſhall therefore, at the End of Mr. *de Valliere*'s Diſſertations annex his Table of charging of Mines, founded on the above Suppoſition, namely, that their Entonnoir is really a Paraboloid. This Table may be of Uſe to ſave the Trouble of making repeated Calculations.

It follows, from that Hypotheſis, which ſuppoſes the Radius always equal to the Line of leaſt Reſiſtance; that, if they would have the Aperture of the Mine, for Example, forty feet Diameter, the Chamber muſt then be twenty Feet in Depth; or, which is the ſame Thing, twenty Feet muſt be allowed for its Line of leaſt Reſiſtance. Thus, again, thirty Feet will be required to make the Excavation ſixty. But, as all Soils will not admit of being dug thus deep, it is evident, that the practical Part of Mining will gain conſiderable Advantage from the preceding Experiments: Becauſe we have there ſhewn, that the Radius of the Excavation of a Mine may exceed the Line of leaſt Reſiſtance; and thereby form wider Apertures, without laying us under a Neceſſity either of digging ſo deep, as is at preſent practiſed, or making many Fourneaus for this Purpoſe.

" But now, to inlarge the Entonnoirs to " any Size whatever, even ſuppoſing that they " cannot have the Lines of leaſt Reſiſtance " large enough, becauſe the Soil will not ad- " mit of their digging very deep; there needs " no more to be done, ſays Mr. *Du Lacq*, " but to make ſeveral Fourneaus, among " which, that in the Center is to be diſtant " from the other ſomething leſs than their " common Line of leaſt Reſiſtance: For then,

" by making each of theſe Fourneaus com-
" municate with that in the Center, and there-
" fore ſetting them on Fire by Means of the
" Central-Fourneau, we ſhall communicate
" this Fire to the ſeveral other Fourneaus pre-
" ciſely at the ſame Inſtant. Thus all of them
" ſpringing together, they will conſequently
" blow-up ſuch Quantities of Earth, as imme-
" diately ſurround them. When the Enton-
" noirs are to be exceeding large, and the
" Earth is to be dug ſo deep, as that one Cir-
" cumference is not ſufficient, to produce the
" deſired Excavation, with this Line of leaſt
" Reſiſtance ; no more is required than to
" increaſe the Circumference of the Four-
" neaus, in order to inlarge the Circle of the
" Entonnoirs. When there is more than one
" Circumference of Fourneaus, and it is ne-
" ceſſary, that the Center-Fourneau com-
" municate Fire to all the other Circumferences
" at the ſame Inſtant, nothing more is to be
" done, than that they make the Trains,
" which are to convey Fire to the ſecond Cir-
" cumference, ſo much thicker, as that both
" of them may be conſumed at one and the
" ſame Time. If there be a third Circum-
" ference of Fourneaus, the Thickneſs of the
" Trains muſt be proportion'd to their Length,

" in ſuch Sort, that all the three Trains may
" be conſumed preciſely together.

" WHEN the Lines of leaſt Reſiſtance are
" of a determinate Length, there will ariſe
" the following Inconvenience. Namely:
" The Center-Fourneau will ſpring before any
" of the reſt, becauſe of the Length of their
" Trains, and conſequently will blow-up the
" Earth which is between the Circumference
" of it's Entonnoir, and that of the neareſt
" Fourneaus; an Event, which cannot but
" diminiſh the intended Effect." Wherefore to provide againſt an Accident of this Kind, it is propoſed by Mr. *Du Lacq*, to make the Center-Fourneau ſmaller and unequal to the Force of the Reſiſtance of the Earth to be raiſed, that by this Means it may prove quite ineffectual; in conſequence of this Step, it will only be conſidered as a kind of Priming, if I may ſo ſpeak, to procure an equal Conveyance to all the Fourneaus, that they may all ſpring at the ſame Inſtant: To this End, however, there is one Precaution neceſſary; which is, that the Space from one Fourneau to the other, as well as from that of the Center, be equal to, or rather a little leſs than, the Diameter of their Entonnoirs.

Of the Fruſtum of a Cone whoſe Figure is, in Plate 10, *Marked* A.

UNSKILFUL Perſons meaſure the Fruſtum of a Cone, by multiplying the Area of the Baſe by the Altitude of the Cone, which is triple the Cone itſelf; then ſubſtracting the little Cone, and taking one third of the Remainder: But this Operation is certainly wrong.

IT is therefore proper, that we have recourſe to Mr. *Ozanam*'s Method, which is, to multiply the Area's of the Baſes together, and from their Product to extract the Square-Root, adding hereto the Area's of the Baſes, and multiplying by one third of the Altitude; the Product will be the ſolid Contents of the Cone * if you have multiplied by Feet, you are then to divide by 216, to find the Cubic Toiſes.

THE AREA of a Circle, that is to ſay, the Baſe of a Cone, is found, by ſquaring the Diameter; which Product being multiplied by 785, and this laſt Product divided by 1000, the Quotient will be the Area of the Baſe of the Cone †.

---

* SEE the Demonſtration of this Rule in Mr. *Belidor*'s Courſe of Mathematics, Pages 154 and 155.

† IT is found more readily by ſaying: As 14 is to 11, ſo is the Square of the Diameter of the Circle, to a fourth Term,

THERE is a ſtill plainer Method for meaſuring the Fruſtum of a Cone, and what may fully Anſwer for Practice. It is barely this: You Meaſure the whole Cone, and then ſubtract the Part that is cut off; as was before obſerved; but to proceed by this Rule, the Altitude of the whole Cone muſt be known; which is eaſily found by operating as follows:

LET a Line, equal to the Diameter of the Baſe of the Cone, be biſected by a Perpendicular; on this Perpendicular take a Part equal to the Altitude of the Fruſtum; from whence draw a Line at once parallel, and equal, to the Radius of the Baſe, ſo that the Perpendicular may biſect it. After this, join the Extremities of the Diameter of the Baſe to thoſe of the Parallel, and produce them 'till they meet the Perpendicular in a Point, which Point ſhall correſpond to the Vertex of the Cone; and

---

Term, which gives the Area of the Circle. The Rule is founded on this Theorem: *That the Diameter of a Circle is to the Fourth of its Circumference, as the Square of it's Diameter is to the Area of the Circle.* We know that the Ratio of the Diameter to it's Circumference, is as 7 to 22, or doubling each Term, as 14 to 44. Then as 14 is to 11, ſo is the Square of any Diameter to the Area of it's Circle. If both Terms, 14 and 11, are multiplied by 1000, we produce 14,000 and 11,000; which having the ſame Ratio; and being divided by 14, give 1000 and 785 for the two Terms, which the Author of theſe Memoirs ſubſtitutes in the Place of 14 and 11.

thus the whole Altitude of the Cone will be that Part of the Perpendicular, which is comprized between that Point and the Baſe: Subtracting therefore the Altitude of the Fruſtum from this Line, the Remainder will be the leſſer Cone, and the Meaſure of the Fruſtum will by this Means become perfectly eaſy.

THIS Problem ought to be performed by making a Scale, whereon the Dimenſions of the given Lines are abſolutely determined: The Lines I refer to are: The Diameter of the Baſe of the Fruſtum; the Diameter of it's upper Part parallel to the Baſe; and it's Altitude.

24 *Diameter of the Circle.*
24

96
48

576 *Product which is to be multiplied by* 785.
785

2880
4608
4032

452160 *Product which is to be divided by* 1000

452160(452 *Greater Area.*

12
12

144
785

720
1152
1008

113040(113 *lesser Area.*

452 } *The two Area's multiplied by each other.*
113 }

5876
452

51076 *From which extract its Square Root.*

51076(226 *to which add the Area's of the two Bases.*
4

42)110
84

446)2676
2676

226
452
113

791 *Product which is to be multiplied by one Third of the Altitude.*
4

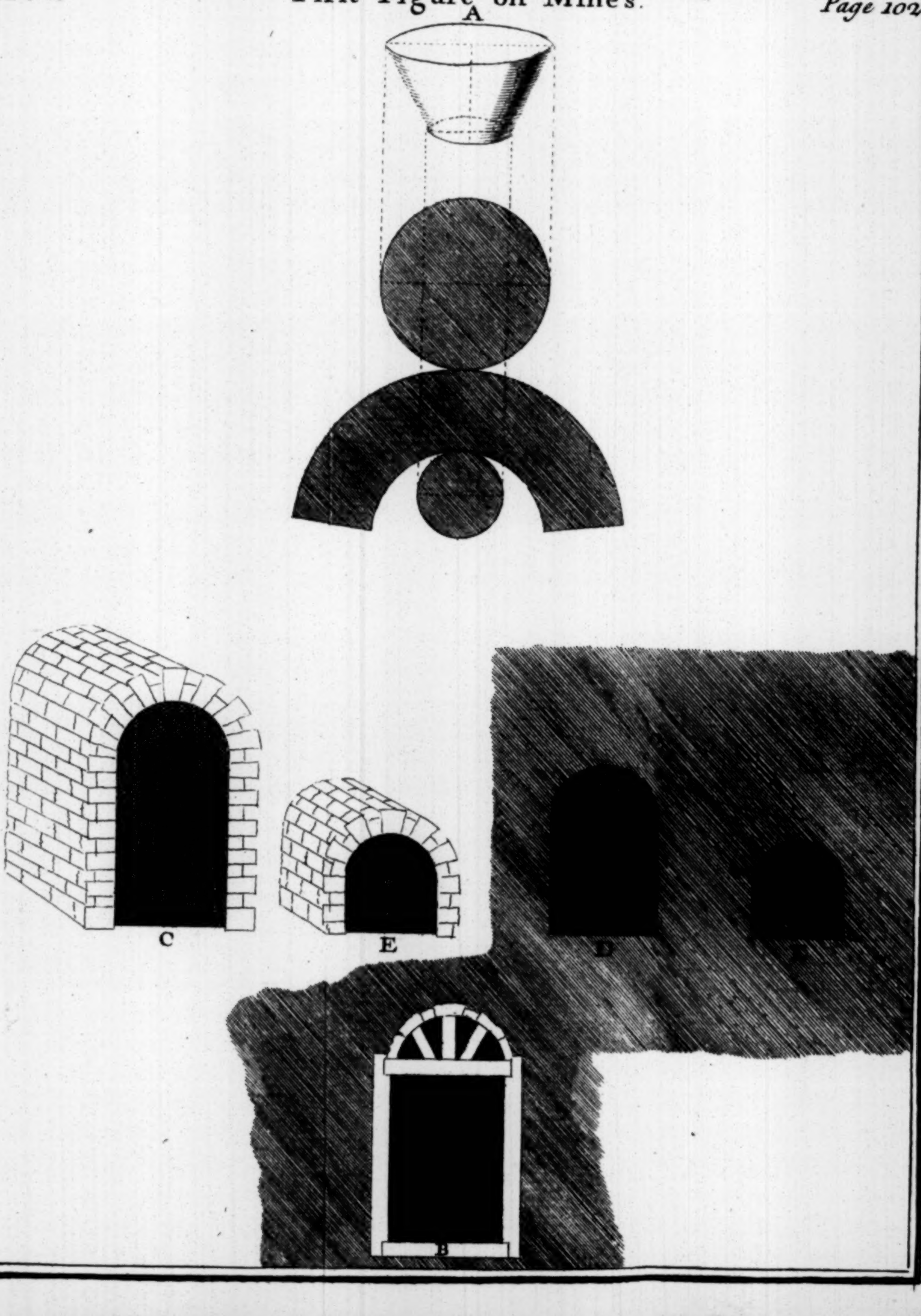
3164 *Cubic Feet contained in the Cone.*

ONE

Pl. 10

Firſt Figure on Mines.

Page 102



One Thing, however, ſtill remains dubious: That is to ſay, whether the Cone is to be formed from the very Bottom of the Fourneau, or only higher up. Mr. *De* ——— aſſerts, that it is from the very Bottom *. Be it, however, which it will, it is of no great Signification. For the Conſequence can only be this: If it begin higher, one Pound of Powder will not raiſe ſo great a Weight as we imagine: For Inſtance, if we fancy it will raiſe one hundred and twenty Pounds, it will in Fact raiſe but one hundred Pounds.

Proportions of the Galleries and Branches.

FIGURE I.

THE Galleries made of Earth ought to be arched over, as we ſee in the Figure *B*, to make them capable of ſuſtaining the Earth, which would otherwiſe fall-in.

---

* We conſider it in our Calculation as beginning at the Center of the Fourneau. This however, is not preciſely true; for as much as the Powder, acting on the Bottom of the Fourneau, always cauſes an Hole there like the Bottom of a Kettle; ſo that the Fruſtum is ſomewhat deeper than the Line of leaſt Reſiſtance. Yet this may be neglected, without any material Error, in the Calculation.

Galleries made of Maſonry, as *C*, are ſix Feet high; For the Piers are four Feet ſix Inches perpendicular, and the Arch riſes by one Foot ſix Inches, and is three Feet wide.

The Galleries of Earth *D*, are four Feet ſix Inches high, and two or three wide.

The Branches *E*, are two Feet wide, and two Feet ſix Inches high.

Of the Different Sorts of Mines.

FIGURE II.

A FOUGASSE, *A*, differs from a Fourneau, in that it is not more than from five to twelve Feet deep; whereas the Fourneau, *B*, is from twelve Feet to all Depths.

The Difference between the Trefle, *C*, and *T* Mine * *D*, is, that the *Trefle* has but two Lodgments, *E*, which buttreſs near the Chamber.

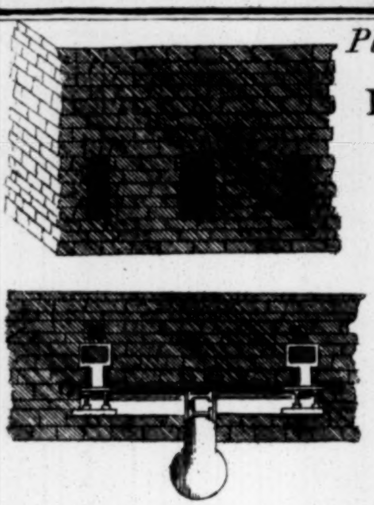
The *T*, or double Mine, has four Lodgments *F*; and inſtead of four Doors *G*, has but two *H*, both which are ſhored againſt each other at the End of the Branch; and by this Means the Charges mutually aſſiſt each other.

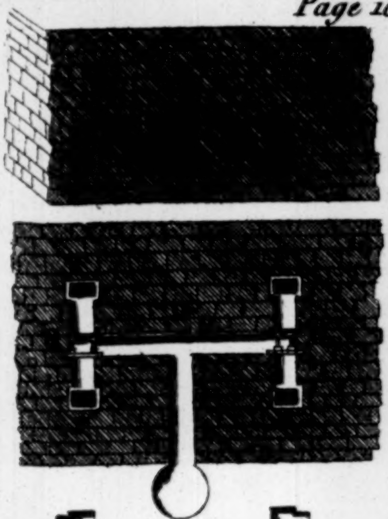
---

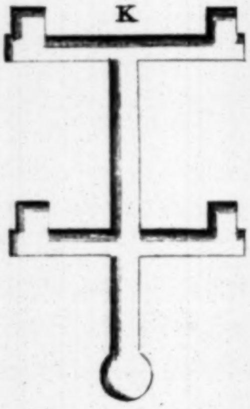
* A Mine ſo termed [*h. e. T* Mine] from the great Reſemblance it bears to that Letter.

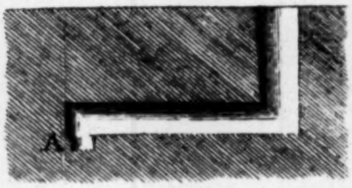
The

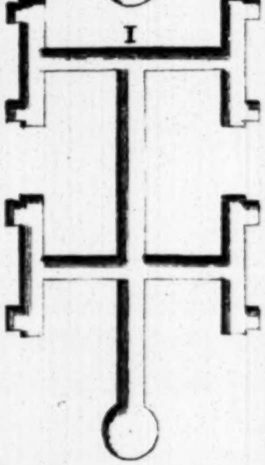
II Figure on Mines

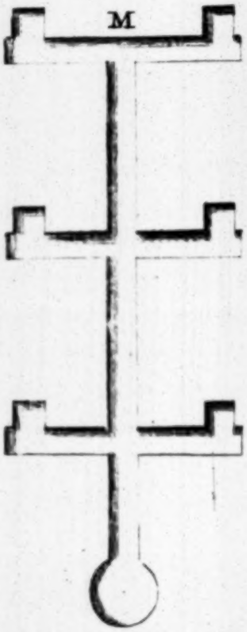


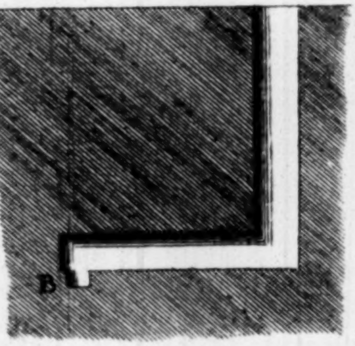


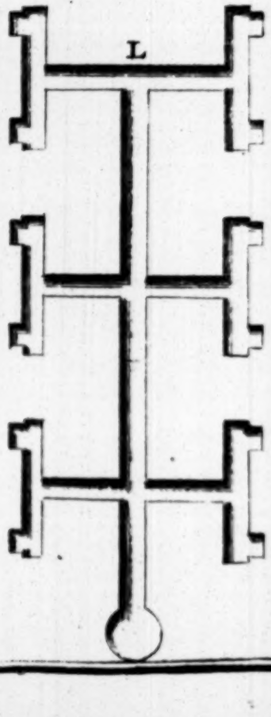












The double *T* Mine, *I,* has eight Lodgments, and but four Doors; the double *Treſle K,* has four Lodgments, and eight Doors.

The Triple *T* Mine, *L,* has twelve Lodgments, and ſix Doors.

The triple *Treſle, M,* has ſix Lodgments, and twelve Doors.

Of the Diſtance of the Galleries.

FIGURE III.

THE Countermines that have been hitherto conſtructed, have not arrived to the deſired Perfection, with reſpect to their Diſtances; for at ——— Experience convinced us, that the Earth might crack on the Sides and at the Bottom, even where there was no Void, to a Semi-Diameter of the Baſe of the Fruſtum of the Cone, which Fruſtum is marked *A*; and likewiſe, that where there is a Void, it may crack on the Sides and at the Bottom, for a whole Diameter of the Baſe of the Cone, or for the Altitude of the Earth above you.

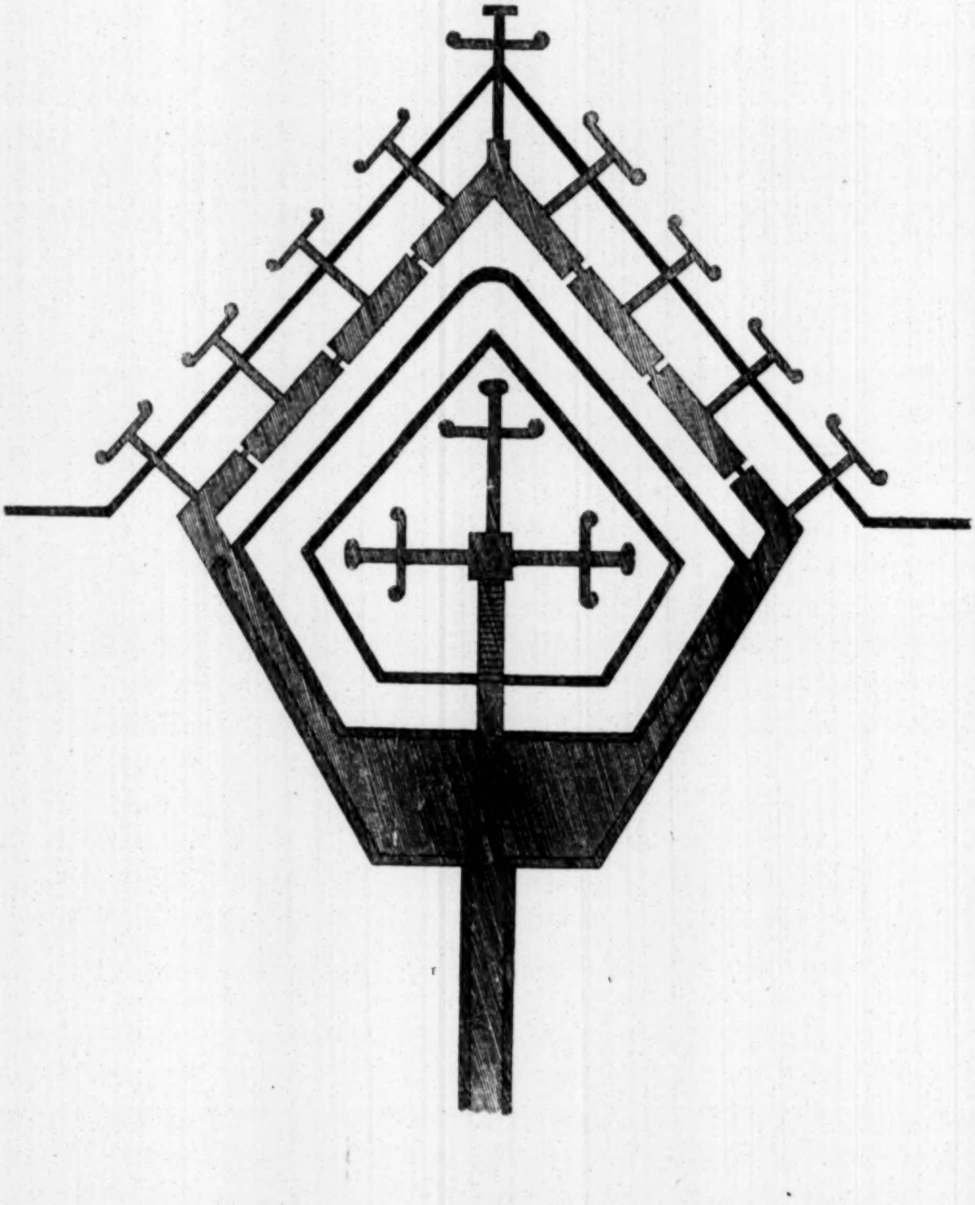
Notwithstanding the Diſtance of a Gallery from a Fourneau which plays, may exceed the Diameter of the Baſe of the Cone; nevertheleſs, it muſt, be propped, ſhored, and walled-up; otherwiſe it will be damaged, as Ex-

Experience has proved on a Gallery, which was placed at forty Feet Diſtance.

Those built with Maſonry are ſtopped-up with Stones and Dung; thoſe of Earth, with Stones and Earth. I leave any Perſon to judge, whether a Gallery, whoſe Diſtance from a Fourneau, which ſprings, and blows-up forty Feet of Earth, is only one, two, or three Toiſes; whether I ſay this Gallery, can remain without Damage. Adding to this, that it is ſometimes above three Days before it can be entered, by Reaſon of the Stench, which continues in the Earth, and infects the Air to ſuch a Degree, that they have been obliged to pull the Miners out by the Heels. Upon this Account it is, that I can by no Means approve of their Maxim; who ſay, that when the Gallery is low, you ought to work over it, and blow-up the Enemies Lodgment, by making a Fougaſſe in that Place; and that afterwards, if the Enemy venture to lodge there, you are then to uſe your Gallery for carrying on Fourneaus to the right and left. This is certainly an ingenious Speculation, but almoſt impractible, for the Reaſons already aſſigned: Becauſe, ſhould it be upwards of three Days before you can have it in your Power to enter the Countermines; reflect, whether in that Time the Enemy's Battery will not have accompliſhed it's Deſign.

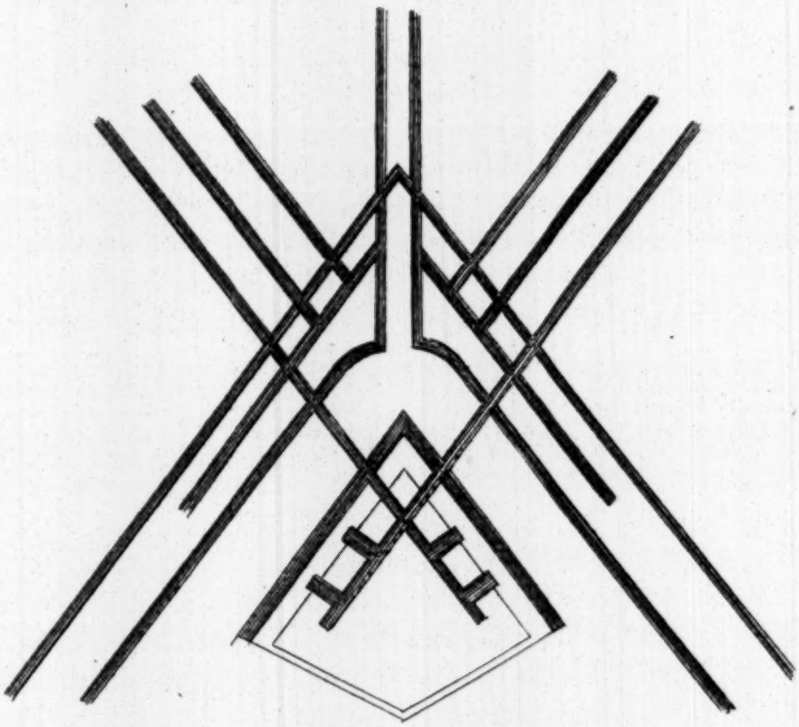
III Figure on Mines.

Plan of the Countermines of the Redoubts of........



Continuation of the 3^{d}. Figure.

Plan of the Countermines of the Lunett of.....



The Rule to be obſerved for the Diſtance of the Galleries, is, that they be $\frac{1}{2}$ of the Depth of the Mine: For Inſtance, if I have thirty Feet of Earth to blow-up, let the Gallery on the Side of it, and that below it, be forty-five Feet, as *B*, which repreſents likewiſe the Section of the Earth, where the Galleries are ſituated.

The Side Gallery does not ſuffer ſo much as that beneath; for, the Powder of the Fourneau, which is to blow-up twelve Feet of Earth, ſounds (if I may uſe the Expreſſion) all round it for the weakeſt Part; and finding it upwards, blows-up whatever is above it; and as I may ſay, ballances the Weight above it with that which is below it.

The other Reaſon, why the Side Galleries do not ſuffer ſo much as thoſe beneath, is, becauſe the Powder acts in an Angle of forty-five Degrees, as we find to be the Caſe in a Shell: For if the Pit it makes, in falling, be four Feet deep, it's Aperture, at Top, in burſting, will be eight Feet.

The Rule for the Diſtance of the Fourneaus *C*, is, that they be three-fourths of the Depth of Earth they are to raiſe; ſo as to be reciprocally aſſiſting to each other, and by this Means leave no Earth between them. It is for this Reaſon, that, the Fires ſhould be ſo accurately diſtanced as to catch altogether.

THE Letter *D*, repreſents a Fourneau, when it plays; and the pointed Lines at regular Diſtances, exhibit the Effect, which the Fourneaus would produce, were they all ſprang together.

CARE muſt be taken to place the Powder at the End of the Branch *E*, where there is no Traverſe, when it is to make a Breach; and in the Center of the Maſonry, as was done at the Counterguard of ———

F CONVEYANCE of the Fires.

On MINES.

FIGURE IV.

IF you would make a Lodgment at the Point *A*, the Gallery muſt not be oppoſite to it, as at *B*; but to the Right or Left, as at *C*; that ſo it may not have the weak Part to the Right of the Lodgment.

THE Gallery muſt not be carried juſt under the Center, becauſe the Chamber ought to be there, when there is only one, as this at *D*.

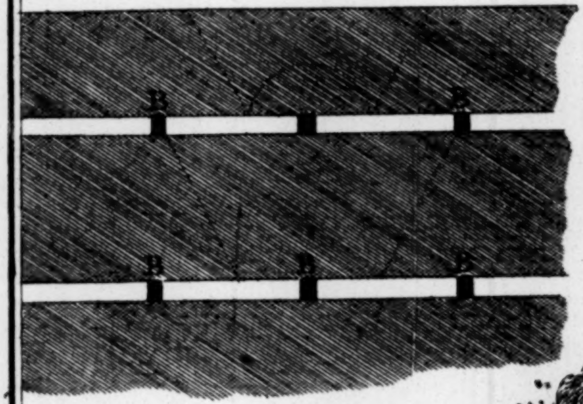
TO the Plan of the *Treſle* E, Traverſes are made; that when the Fourneaus ſpring, they may not damage the Gallery.

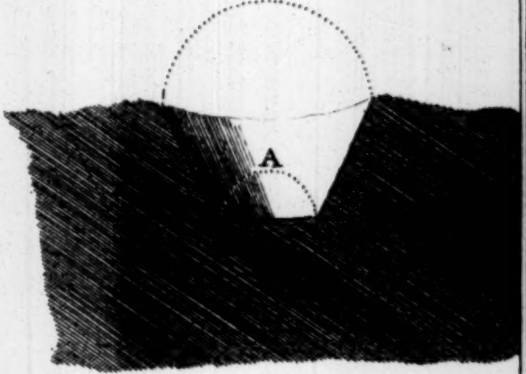
THE

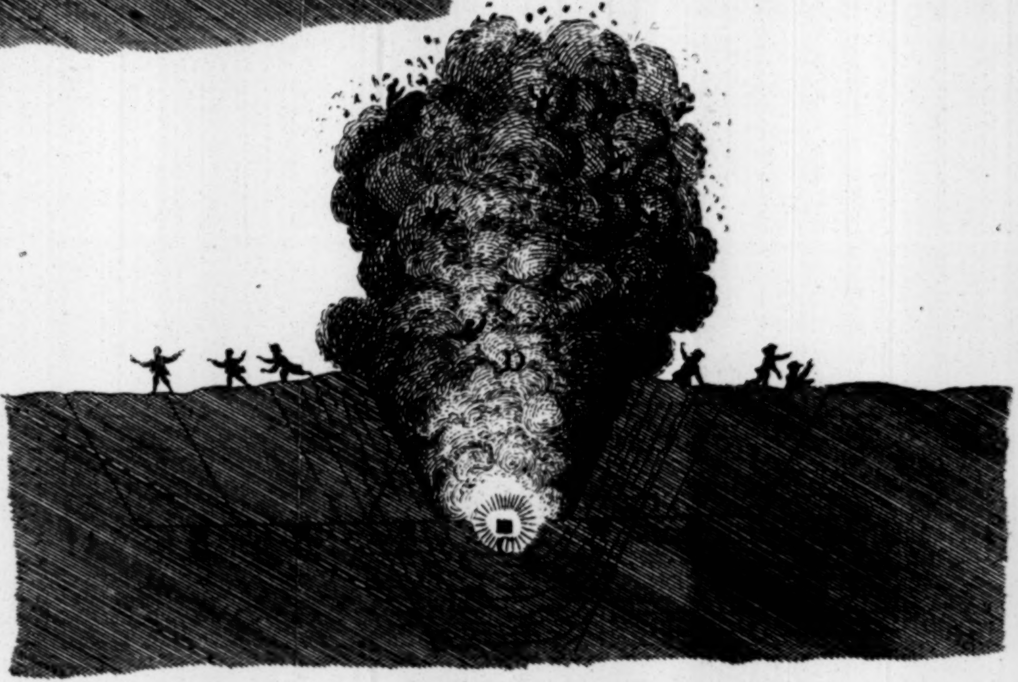
Pl. 14

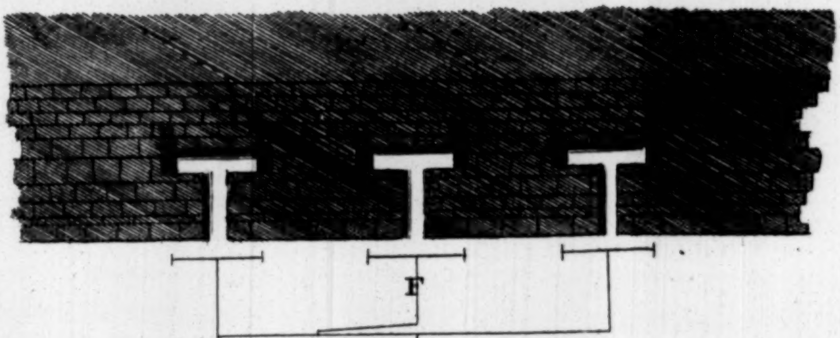
Continuation of the Third Figure.

Page 108









The Galleries ought to be ſhored, walled, and ſtopped-up at each third Turning, one Fourth, or one Third, more than the Weight of Earth above the Powder; and that ought to be reckoned in a direct Line. For Example: *F*, *G*, *H*, and *I*, muſt be one Fourth, or one Third, longer than the Height above it; and *K*, *K*, one Fourth, or one Third, longer than the Height of the Earth.

L, A Fourneau at Right-Angles.

At each Angle is placed a double Door; that is to ſay, Planks are ſituated ſome vertically, others horizontally, with two Piers; on each of which Piers are placed three Props.

It is better to lodge rather too much Powder, than too little; but the Flame ought not to appear; for if it does, it is a Sign it was overcharged

M *The Pier againſt the Earth.*
N *Planks fixed againſt the Door.*
O *The Door.*
P *Props or Shores.*
Q *A Wedge.*

The Piers ought to incline more towards each other, at the Bottom, than at the Top, to prevent the Props from falling, when thoſe below are drove in.

In the Countermines marked *R*, at the Citadel of ——— there are Croſs-Bars, *S*, to ſecure the ſeveral Angles.

This is the Method of Mining when a Breach is to be made, eſpecially in old Maſonry, lined with Earth.

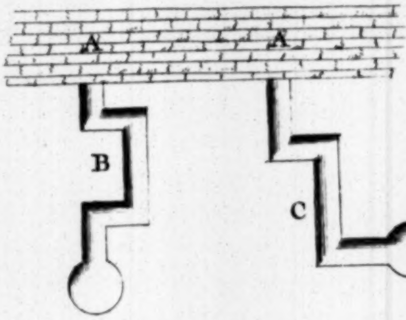
On MINES.

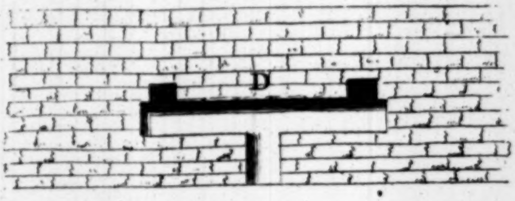
FIGURE V.

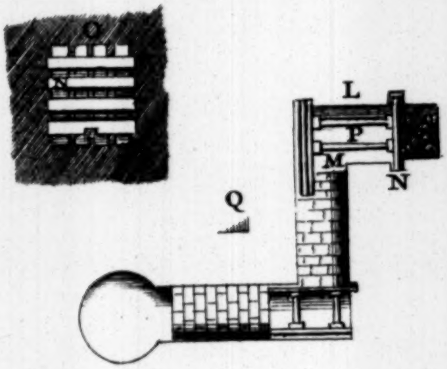
WHEN you would throw the Face of a Baſtion into the Ditch, Fourneaus muſt be made in the Center of the Maſonry *A*, whoſe Lodgments are to be at the End of the Branch *B*, long-ways, without a Traverſe; and other Fourneaus in the Earth *C*, which are to be ſituated between the former Fourneaus; as was done at the Counterguard of ——, for the Deſign is only to cut the Bottom of the Wall.

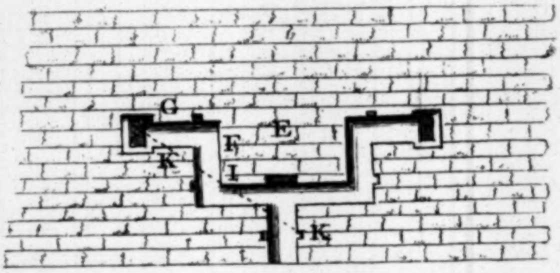
Though at the Tower of *Reme D*, the Fourneaus and Fougaſſes *E*, were placed under the Foundation; yet that ought to be no Rule: For it is better to leave two Feet of Maſonry to lodge the Powder in, than to put it on the Ground. The Fourneau by this Means, will be leſs liable to get Vent; and do more Execution among the Soldiers in the Trench.

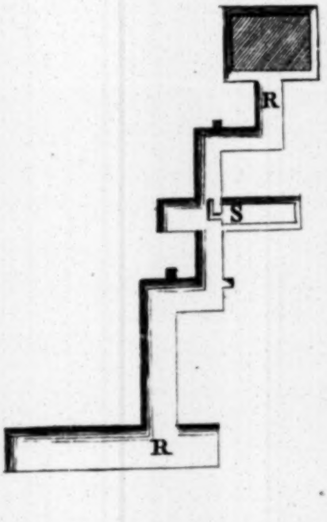
IV Figure on Mines.











The Wall ought to be pierced through to the level Ground, and a Gallery *F*, made between the inſide Edge of the Wall, and the level Ground, and Fourneaus *G*, conſtructed in the Earth, about three Toiſes diſtant from each other; and again, other Fourneaus, *H*, in the Maſonry, on a parallel Line, and about three Toiſes diſtant likewiſe; with one hundred Pounds of Powder in each Fourneau; taking Care alſo that there be ſeveral Entrances and Ways out, that the Enemy may not have it in his Power to blockade your Paſſage.

Masonry is meaſured by multiplying the Length, Height, and Thickneſs together; and the laſt Product will be the ſolid Contents of the Wall, in ſolid Feet, ſuperficial Feet, or whatever Meaſure you uſe.

The Fourneaus in Maſonry ought to advance a little beyond the Earth, to render them capable of throwing down what is not fallen: This is effected by making the Sauciſſon more long or ſlender.

To find the Dimenſions of a Chamber, ſufficient to lodge one thouſand Pounds of Powder; I ſay, by the Rule of Three: If ſeventy Pounds give one cubic Foot, what will one thouſand Pounds give? Which is fourteen cubic Feet, the Quotient, or fourth Term, ſhews how many cubic Feet the Fourneau ought to contain; and then multiplying the Quotient by 70 *, you will find the Quantity contained in fourteen cubic Feet, which anſwers by way of Proof.

The Chamber ought to be eighteen Inches higher than is neceſſary for the Powder alone, that it may be conveniently lodged, and overpropped.

$$\begin{array}{r} 70 : 1 :: 1000 \\ 1 \\ \hline 7|0)\,100|0(14\tfrac{2}{7} \end{array}$$

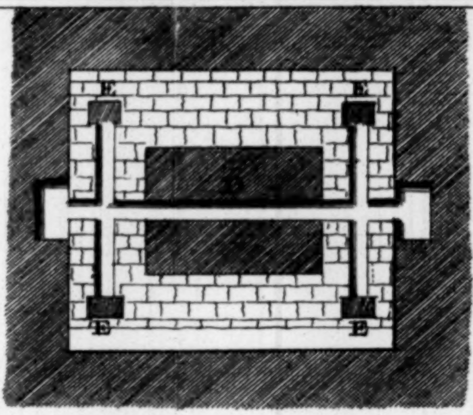
$$\begin{array}{r} 14 \\ 70 \\ \hline 980 \\ 20 \\ \hline 1000 \\ \hline \end{array}$$

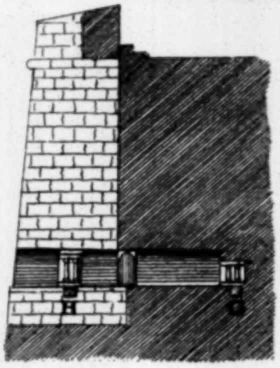
---

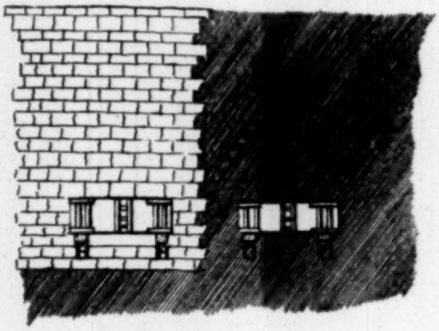
* It is ſuppoſed here, that a Cubic Foot weighs only ſeventy Pounds; now we have before ſhewn at Page 66 that it was commonly ſuppoſed to weigh eighty Pounds; tho' it has likewiſe been found to weigh ſixty-five, and ſeventy-one Pounds: Since therefore the Weight of all Powder is not the ſame, it is very eaſy to examine the Weight of each Sort, by weighing the Quantity requiſite to fill a Foot-Cube.

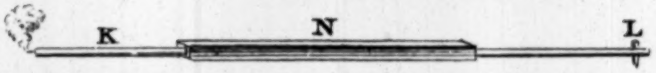
Pl.16 *Page 112*

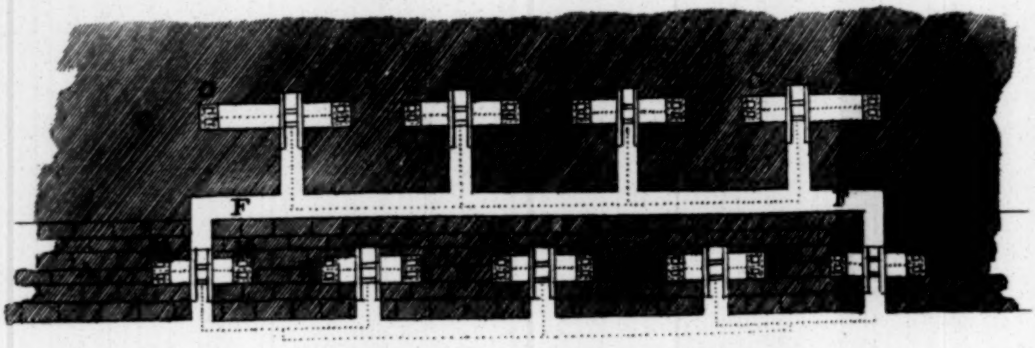
V Figure on Mines.

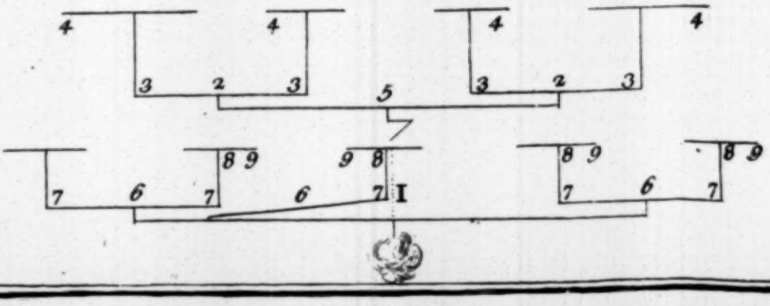












The beſt Method for proping-up the Powder, is, to make the Lodgment like a Well, and to ſhore and prop-up the Earth above it. After this, let a double Door be placed at the End of the Branch, in ſuch a Manner, that the Top of the Fourneau may be level with the Bottom of the Branch; becauſe the Earth, or Maſonry, which has not been moved, is always ſtronger than that which has: And the Length of the double Doors ought to exceed their Breadth, becauſe it is proper they ſhould enter ſix Inches on each Side into the Branch.

Of the Diſpoſition of the Fires.

ALL the Fourneaus muſt abſolutely, catch Fire, at the ſame Inſtant, which is eaſily performed. Let the Diſtance of the two Fourneaus be meaſured with a Piece of Packthread, then half the Length of this Packthread will be the Length, which each Sauciſſon ought to be of, when the two Fourneaus are equal: Let two other Fourneaus be joined to thoſe above, at the Part where theſe Sauciſſons terminate; then take a Packthread and meaſure their Diſtance, the half of which, again, ſhall be the Place for the general Fire. In Plate 16, 1 and 5 are the principal Fires; 1 is the chief Fire: The other Parts of the

Figure ſufficiently ſhew, how the Fire communicates itſelf to the Fourneau by the Figures, that follow the above 1 and 5.

THE AUGETS which come from above, are put into ſmall Gutters, which are made in the Piers of the Gallery; and there ought to be one Foot of Earth between two Augets, for fear they ſhould not communicate the Fire.

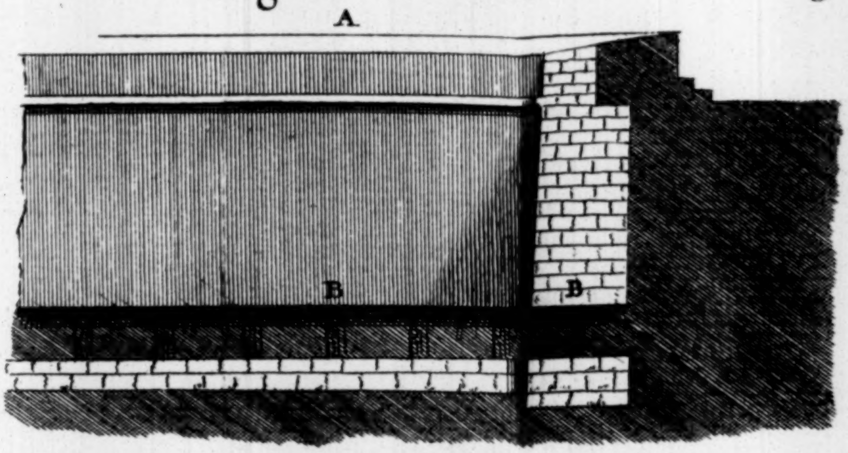
THE POWDER muſt not be tied in the Sauciſſon, *K*, leſt the Fire ſhould not catch, and there ought to be a Peg, *L*, put at the End of the Sauciſſon.

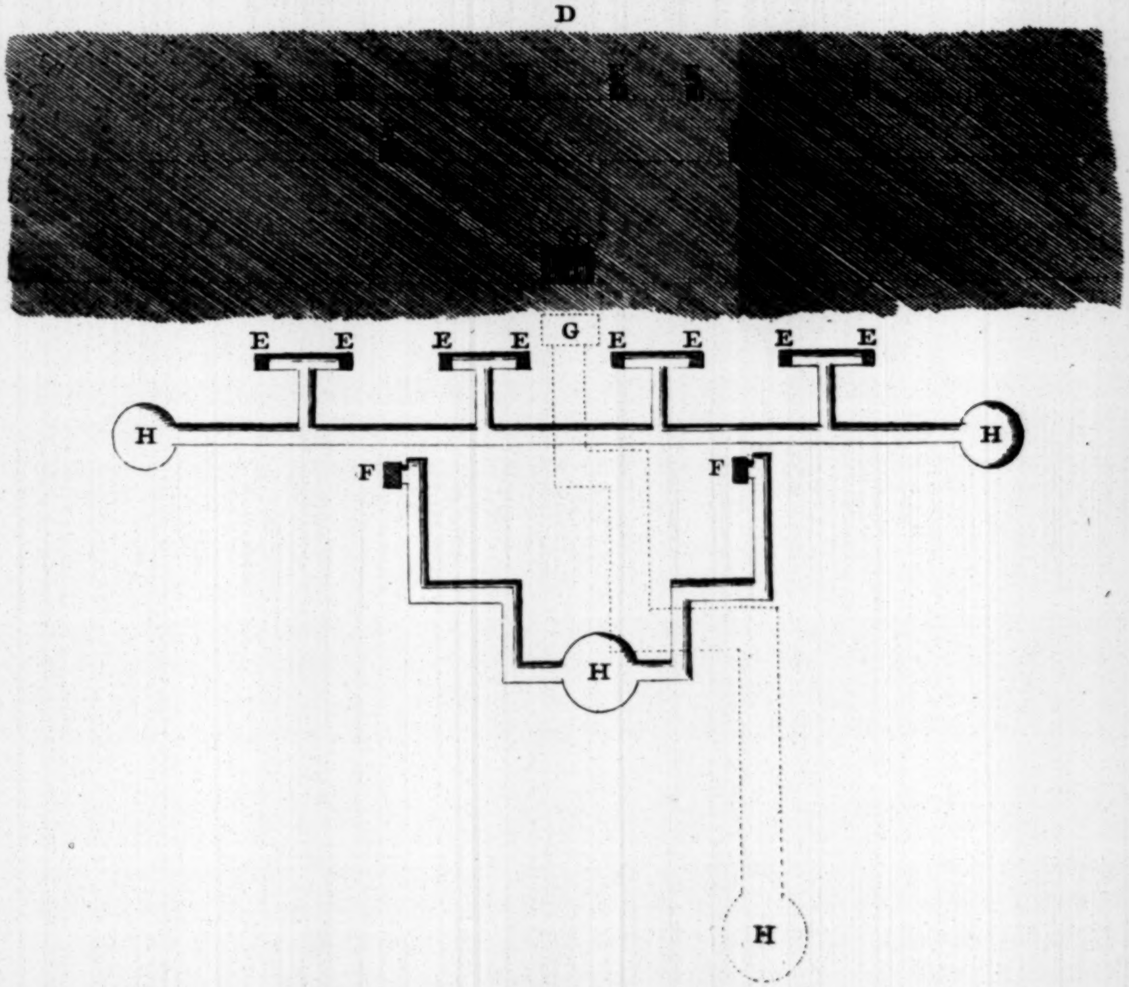
THE POWDER ought to be carried in Leather Bags, *M*. The Sauciſſon is one Inch Diameter: To fill one Foot of it ſeven Ounces of Powder are neceſſary.

THE AUGET, *N*, ought to be an Inch, and an half Square, in the clear. The Lodgments of the Galleries of Earth are to be arched over, to prevent the Earth from falling-in and overwhelming them. And when there happens to be Water at the Bottom of the Chambers, the Powder, and Sauciſſon, are to be put into tarred Sacks.

THE MINE acts ſtronger on that Side, where there are no Props, than on that, where there are. There muſt be a ſhelving from the Fourneau to the Entrance of the Gallery, that in Caſe any Water ſhould ſtrain through the Earth, it

VI Figure on Mines.





it may run into Pits dug for that Purpoſe *. There ought to be no Lodgment, but what they intend to charge.

On MINES.

FIGURE VI.

THE FIGURE *A* repreſents in what Manner the Wall *B* is to be ſapped, by proping-up the Hole as the Miner advances, with the Piers *C*; the Holes for which ſeveral Props are to be bored into the Earth with a proper Augre. After having ſapped the Brick-wall quite through, and to the Extremity of it's whole Length, they lay a Train of Powder for blowing it up.

THE FIGURE *D*, repreſents the Section of the Earth, and how to ſpring the above Props, at ſeveral Times.

THE FOURNEAUS *E*, are made to blow-up the Earth which is over them.

THE FOURNEAUS *F*, are to blow-up the ſecond Surface of the Earth.

---

* This Obſervation is of the utmoſt Importance; for, ſhould the Enemy convey Water into the Mine, it will render it ineffectual; as happened at the Siege of TURIN. But if the Fourneau be formed above the Gallery, the Water cannot reach it, unleſs the Enemy find Means to lay all the Galleries under Water.

The Fourneau *G*, ſhews how the Remainder is to be blown-up.

H are Pits at the Ends of the Galleries, which communicate with the Fourneaus.

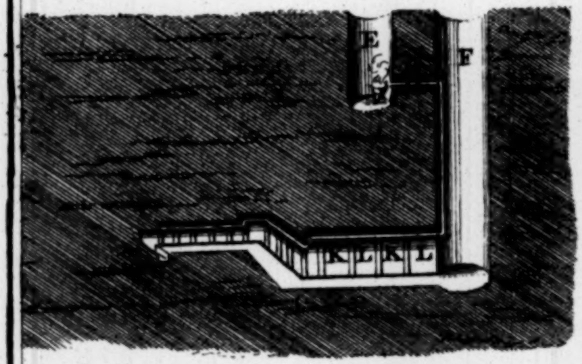
On MINES.

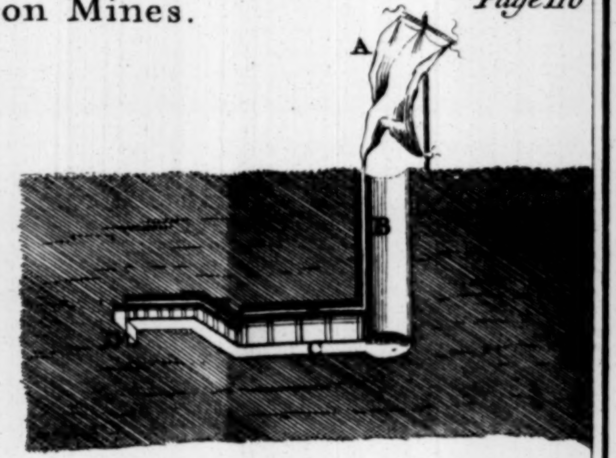
FIGURE VII.

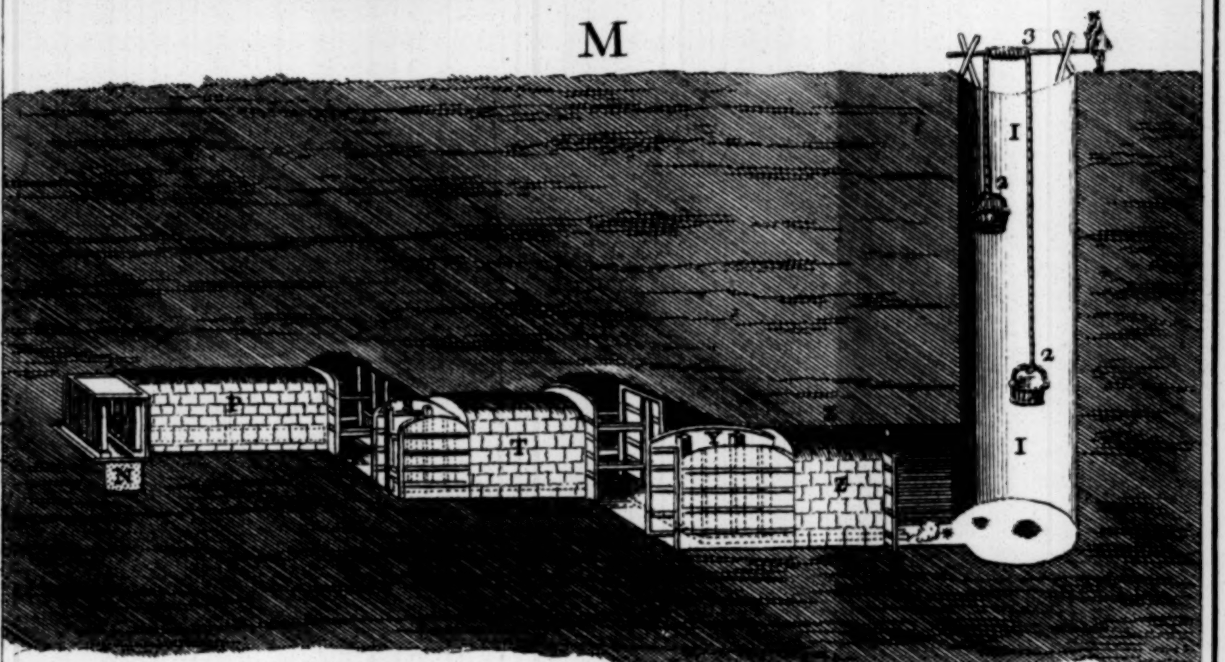
THERE are ſome Galleries, where they cannot breathe, or keep a Candle lighted, either becauſe there is a real Deficiency of Air; or, at leaſt, becauſe it does not duly circulate: Wherefore, to remedy this Inconvenience, they have a large Sail *A*, to which a Sack is fixed, with a leather Pipe *B*; this Pipe goes through the Gallery *C*, to the Fourneau *D*, and cauſes the Air to circulate, provided it be not too denſe.

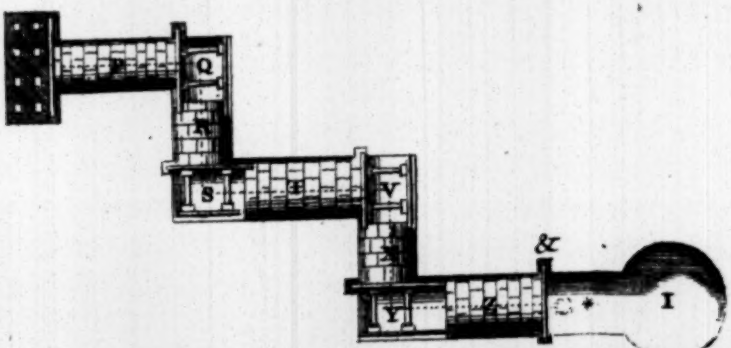
There is another Machine, that was made uſe of at ——— Which is ſtill preferable. It is a ſmall Well *E*, near a larger Well *F*, which has a Communication *G*, by means of a leaden Pipe *H*, that reaches to the Bottom *I*; after this, Notches are made in a Pier, *K*, of the Gallery, of eight Inches, and the Merlons, *L*, are bored: Theſe Notches are cloſed with Planks, where a Fire is made, in the little Well *E*, in a Chafing-Diſh, and kept continually

VII Figure on Mines.









ally blowing, which rarifying the Air, makes it circulate: The Perſon who is in the Gallery, keeps up the Fire; while, by this Means, the great Well furniſhes the Gallery with it: We ſuppoſe however, our Readers are fully appriſed, that when theſe Inventions take Place, they who uſe them, are abſolute Maſters of the Ground.

THE FIGURE *M*, repreſents a Section of the Earth, wherein is marked the Courſe, which the Galleries and Branches take in the Ground, in order to conduct themſelves to the Fourneau; together with the various Shorings.

N. *The Chamber filled with Powder.*
O. *The Shoring above the Chamber.*
P. *The Maſonry from the Chamber to the firſt Turning.*
Q. *The Shorings with thick Planks, Piers, and Props to the firſt Turning.*
R. *A Space that ought to be walled-up, as it is marked in the Plan, but omitted in the Profil, that the Shoring in the firſt Turning* Q *may be ſeen.*
S. *The Shoring of the ſecond Turning with thick Planks, Piers, and Props.*
T. *The Maſonry between the Props from the ſecond to the third Turning.*
V. *The Shoring of the third Turning.*

X. *The Maſonry of the third and fourth Turning, which cannot be ſeen in the Profil for the Reaſons before given.*
Y. *The Shoring of the fourth Turning.*
Z. *The Maſonry from the fourth and laſt Turning to the Entrance,* &c.
* *The Fire given to the Sauciſſon.*
The Courſe of the Sauciſſon is marked with a pointed Line on the Plan.

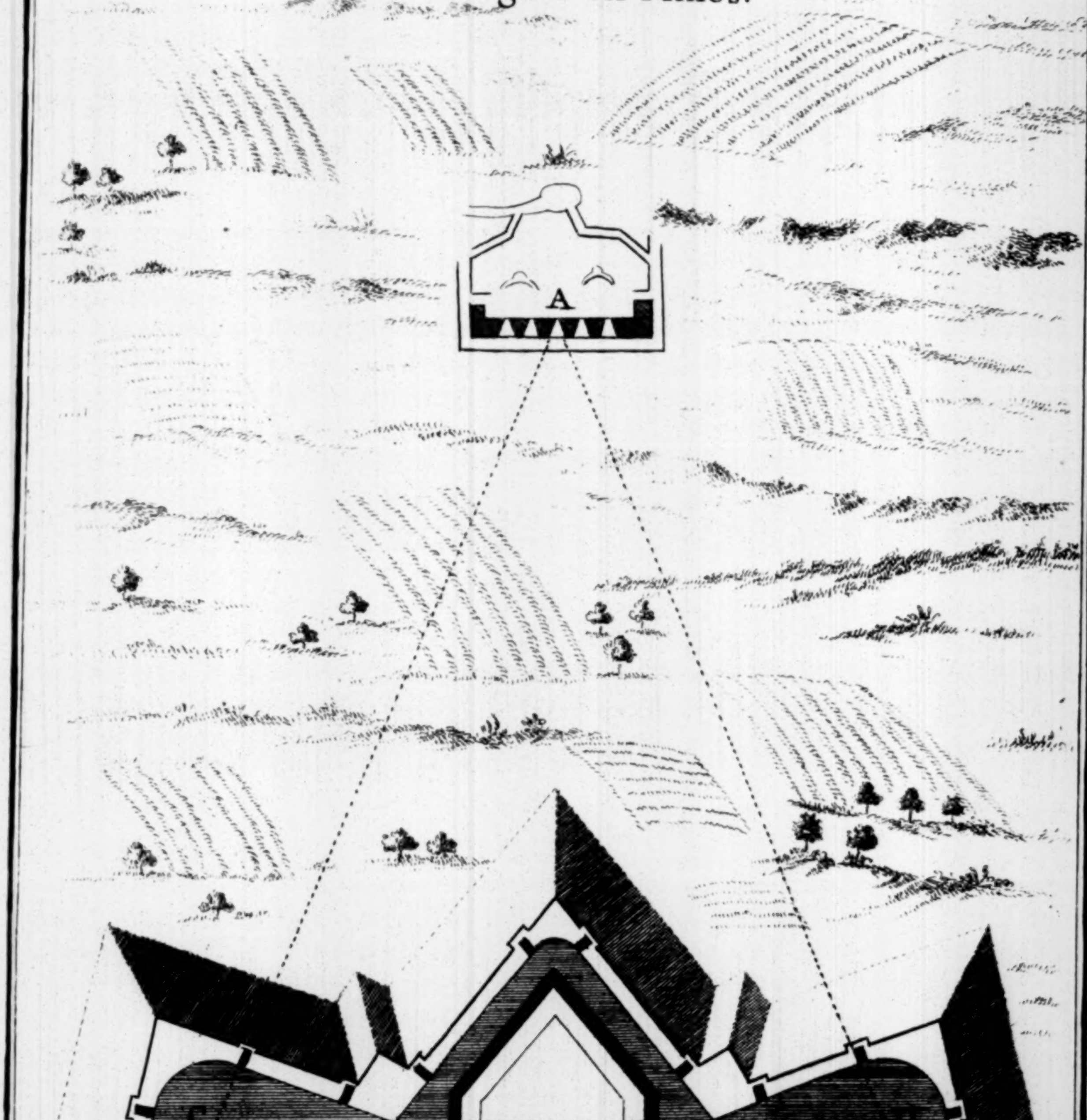
1. *Is what they term the Well, which is the firſt Thing attempted in order to bore the Galleries.*
2. *Baſkets, or Hand-Barrows, which are uſed to draw-up the Earth out of the Galleries, and to let down whatever the Miner wants.*
3. *The Axle-Tree round which the Rope winds.*

On MINES.

FIGURE VIII.

IF you would blow-up a Battery *A*, without the Town *B*, whoſe Diſtance you don't know; place your Protractor on the flanked Angle *C*, putting the two fixed Pins, at the flanked Angle *D*; ſee what Angle the Battery *A* makes with this Baſe; repeat this Operation at the other flanked Angle; then transferring the Work to your Plan, you will there find the Gallery neareſt this Battery. By this means, you

VIII Figure on Mines.



you will ſee, how much of this Gallery is compriſed in the Angle traced on your Plan, and will proceed by right Angles to the Battery: Or, operating in a different Manner, you may proceed to your Battery by other Angles, which you may trace in the Galleries themſelves with a large wooden Protractor, after you have taken the Degrees of the Angles very exactly in the Field, by making a very accurate Plan of thoſe Countermines, and then tracing the above Angles through the Centre of the Galleries.

THE Officer who favoured me with theſe Memoirs, annexed to them a Table of the ſpecific Gravity of a Cubic Foot of the following Materials; I place it here to ſave my Reader the Trouble of ſeeking elſewhere:

Iron,	579
Pewter,	576
Braſs,	548
Copper,	648
Silver,	744
Lead,	828
Mercury,	$977\frac{1}{7}$
Gold,	1368
Gravel,	124
Potters-Earth,	135
Clay,	115
Looſe Earth,	$95\frac{1}{3}$

River-Sand,	132
Sand,	120
Mortar,	120
Brown Free-Stone,	120
Brick,	133
Tile,	127
Slate,	156
White Lime Plaiſter,	86
Stone,	140
Stone of *St. Leu*,	115
Hard Free-Stone, as Stairs, *&c.*	165
Blue-Stone of *Tournay*,	125
Marble,	252
Gunpowder,	70
Salt,	$110\frac{2}{7}$
Wheat,	55
Honey,	$104\frac{2}{5}$
Ozier Wood,	37 9 Oz.
Green Oak,	80
Dry Oak,	60
Eldar,	$37\frac{7}{11}$
Wine,	$70\frac{4}{5}$
Brandy,	67
Freſh Water,	72
Salt Water,	$73\frac{5}{7}$
Wax,	$68\frac{8}{11}$
Lime,	59
Oil,	$66\frac{5}{8}$

A DIS-

A

DISSERTATION

BY

Mr. de VALLIERE,

Lieutenant-General of his Majeſty's Forces, and Inſpector-General of the Artillery-Schools; *on* MINES, *and their Advantage in the Defence of Places.*

I SHALL not here enter on a Diſcourſe about the Conſtruction of Mines, Countermines, the Poſition of Liſtners, Fourneaus, their Charges, nor the Manner of uſing them. This Diſſertation is only intended to exhibit an Idea of the Advantages ariſing from Countermines, provided they are properly conſtructed and defended. Amply to explain the whole Art, would require a Detail of the practical Part: And not to mention the trigonometrical Computations, it would likewiſe be neceſſary to introduce a Theory on the Colliſion of Bodies; the Communication of Motions; the Reſiſtance of Solids; on the various Forces of Percuſſion, and the Elaſticity of Flame, ariſing from different Quantities of Powder: And again, on the different Times and Methods, in which Powder is obſerved to take Fire in the ſeveral Sorts of Fire-Arms, according as the Fire is conveyed: And, in ſhort, we ought previouſly to acquaint ourſelves with a Phyſico-Mathematical Knowledge of Things: All which Particulars, requiring a Chain of Demonſtrations, would abſolutely make-up a large Volume to which the preſent Diſſertation could only ſerve as a Preface.

WHEN *Spain*, took the Kingdom of *Naples* from the *French*, *Francis George*, an *Italian*, who ſerved at *Naples* in Quality of an Architect, propoſed to *Peter de Navarro*, General of the *Spaniſh* Army, who at that Time laid Siege to the *Caſtel del Ovo*, a Method for his becoming very ſoon Maſter of that Caſtle. The *French*, therefore, who defended it, were the Firſt, that experienced the Effect of Gunpowder in Mines.

THE ARCHITECT undertook the Work, and, whether by his Knowledge of the Cauſe, or by good Luck in lodging the Powder, accompliſhed it ſo effectually, as to throw Part of the Caſtle, and Garriſon, into the Sea. This then is the Origin of Mines, invented, indeed, to facilitate the taking of Places; but, found, on the contrary, though not ſufficiently obſerved, to be of much greater Importance for their Defence.

WE know, that the Perfection of Arts and Sciences is reſerved for ſucceeding Generations. With reſpect to the Science of Mines, judging of it by what is already practiſed, there are certain Verities, which, for what at preſent appears, have not, as yet, been diſcovered. However, from the little we know of theſe Matters, we are led to deduce ſuch Facts and Methods for the more commodious Defence of Places, as it would, undoubtedly, be highly culpable in us to neglect.

WHAT I have ſeen on the Conſtruction and Effect of Mines written with the greateſt Preciſſion, are certain Memoirs founded on a Variety of Experiments, which were made about twenty-five Years ſince. The Charges, which are there given to Mines, and the different Apertures they produce in the Earth, according to their different Lines of leaſt Reſiſtance *, may be allowed tolerably correct. I ſay tole-

---

* I term that, ſays Mr. *de Valliere*, the Line of leaſt Reſiſtance, which, being drawn from the Center of the Fourneau, falls perpendicularly on the oppoſite Plane: It is by this Plane that the Powder acts, and this Line is the ſame with the Axis of the pretended Cone.

rably correct, becauſe there is a certain Rule and geometrical Accuracy to be obſerved, in theſe Things, of which we find no mention in thoſe Memoirs. For Inſtance, it is judiciouſly remarked, on Demonſtrations founded in Practice, that a leſs Quantity of Powder is requiſite, in Proportion to the Maſſes, for a large Line of leaſt Reſiſtance, than for a ſmall one: And the plauſible Reaſon, which ſome alledge for it, is, that a great Quantity of Powder has proportionably a greater Force, than a leſs Quantity. But thoſe, who argue in this Manner, might ſoon have diſcovered the Falſity of this Opinion, if they had reflected, that equal Attention is to be paid, both to the Weight that is to be blown-up, and to the *Coheſion* of the Parts which are to be ſeparated: That this Weight is always in the triplicate Ratio of the Line of leaſt Reſiſtance, and it's *Coheſion* only in the duplicate Ratio: That in ſimilar Solids, the greater have leſs Area with reſpect to their Maſſes, than the leſſer have with reſpect to theirs: That the Tenacities in ſimilar, and homogeneous, Solids, being meaſured by their Surfaces, bear the ſame Proportions: And laſtly, that the Charges of Fourneaus, according as they are greater, and conſequently deeper, ſhould decreaſe in Proportion to the Tenacities; or, which is the ſame Thing, to the Squares of their Lines of leaſt Reſiſtance: And that this Decrement, ſhould be made on the Charge firſt eſtabliſh'd by the triplicate Ratio of theſe Lines of leaſt Reſiſtance.

THIS DISCOURSE treating ſolely on the Proportion of Charges, demonſtrates the Neceſſity of Geometry in the Uſe of Mines. A bare Knowledge of the practical Part, will be ſo far from enabling the Engineer to comprehend what has been now advanced; that he will even meet with Caſes, in which, on account of his Deficiency in Theory, he will but rarely ſucceed. It will, neverthelеſs, be ſufficient for the Attack of a Place, where there are no Countermines; becauſe, where nothing obſtructs the Miner's Paſſage, it is eaſy to blow-up a Counterſcarp, and make a Breach in a Baſtion: And, if it ever happens, that Mines do not ſucceed with this Readineſs and Eaſe, it beſpeaks an unpardonable Ignorance in thoſe, who undertook to conſtruct them; unleſs ſome unforeſeen Accident of a heterogeneous Nature ariſe, and neceſſitate the Powder to a different Effect, from that which is natural to it, where the Maſs is intirely homogeneous. But this bad Succeſs happens oftener through Ignorance, than any local Diſadvantage: So that a ſkilful Engineer will generally diſtinguiſh the Places, where there may be Reaſon to ſuſpect any ſuch

Inconveniencies, and if there appear no Remedy in the Caſe, will, at leaſt, think himſelf obliged to acquaint the General with his Fears.

PROPER Care, as yet, has not been taken to diſtinguiſh in what reſpect the Term *Countermine**, agrees to Mines prepared for the Defence of Places. All, however, know, what Obſtructions they are capable of giving the Beſiegers; not but the Annoyance they have hitherto met with from Countermines, is trifling in Compariſon of what they are farther liable to ſuffer from Works of this Nature. I ſhall not aſſert indeed, that theſe Countermines have it in their Power to render a Place impregnable; but thus much I will venture to ſay, that, being artfully managed, I ſee no Way to ſurmount the Obſtacles they may occaſion, nor to ſucceed in an Attack, which is methodically countermined, and ſkilfully defended.

THOSE therefore will do me Juſtice who ſuppoſe, that I am here ſpeaking of a Place conveniently ſituated for Mines; fortified on the Principles of a good Syſtem; furniſhed with a Garriſon ſufficient for Matters of common Defence; well provided with warlike

---

* Becauſe being underſtood in their full Import, they are abſolutely againſt the Beſieger, and intirely prevent his making any.

Stores and Proviſions; and whatever elſe Experience has convinced us to be neceſſary.

An Engineer who is properly ſkilled in the Manner of uſing Countermines to the beſt Advantage, can ſtop the Enemy's Miner, and ſo ruin his Work, as to render it impoſſible for others to carry it on in the ſame Place. He may likewiſe, ſhould he ſuffer him to enter the Galleries, intirely block-up the Way by which he entered, and take him Priſoner. There are ſome Caſes, however, where it may be proper to ſurprize, and kill, him in his Hole. In ſhort, the Beſieged, where expert in the Uſe of theſe ſeveral Advantages, will always have the Fate of their Enemies at their own Diſpoſal. For, without entering on a Detail of the ſeveral Difficulties and Stratagems, which the Enemy's Miner can never foreſee, it will be very eaſy to reduce him to ſuch Circumſtances, as that he ſhall find it impoſſible to carry on any Mine, that might be to his Advantage; ſince all ſubterraneous Paſſages may be ſo blockaded, as to prevent his making any Advance. For it can never be imagined, that he will be ſo obſtinately deſperate as to venture the Countermines of the Place, and carry on his Attack in Form; much leſs that his Perſeverance will be Proof againſt all the Annoyances the Beſieged may cauſe him, not only in his Approaches to, but likewiſe in his Lodgment on, the Covert-Way, and, in ſhort, wherever his Raſhneſs may be ſuppoſed to lead him.

If he arrive at the Covert-Way by Sap, it will be Time to inform him of his Danger by ſome Fourneau: If he attack Sword in Hand, Mines then appear quite uſeleſs. It is indeed, true, they may ſhake the Enemy's Troops during the Attack, and bury ſome of them in the Rubbiſh; but as the Entonnoirs will ſerve for Lodgments, it will be more proper to reſerve the Fourneaus for throwing-down the Works, and conſequently for gaining of Time: Beſides, it is better to defer charging theſe firſt Mines, till it becomes neceſſary to have them ſprang. Not but Care ſhould be taken to have them always in ſuch Readineſs, as may enable the Beſieged to prevent the Arrival of the Enemy's Miner, which, it is eaſy to ſee, muſt be impracticable, when the Mines are once charged. The Enemy, being arrived at the Covert-Way, while he is compleating his Lodgment, may eſſay a Re-entrance under Ground; but he will be again obſtructed, and find on all Sides the ſame Difficulties as before. Immediately upon his beginning to make Epaulments for his Batteries, to batter in Breach, it will be proper to ſpring theſe firſt

Mines, and intirely demoliſh this Lodgment on the Covert-Way. There are good Reaſons for making this Uſe of our firſt Mines, and therefore for waiting till ſuch Time as the Batteries are raiſed. Theſe firſt Mines diſengage and looſen the Earth where the Enemy's Cannon is to be mounted, and of courſe facilitate the Operation of the other Mines for diſlodging ſuch Cannon from the Side of the Place. When this Lodgment is rebuilt, which will require ſeveral Days, and the Cannon replaced, the Fourneaus, which I take for granted are diſpoſed in due Order, and properly charged, will throw them into the Ditch. An Adventure of this Kind cannot but aſtoniſh an Enemy; for here is another Lodgment to be made, and other Batteries to be raiſed: Neverthleleſs, as there are other Mines ſtill remaining which will throw their Cannon again into the ſame Ditch, it muſt ſtill conſiderably heighten his Conſternation. And ſuppoſing him yet bold enough to venture a third Time, he may be ſure to meet with the ſame Reception. In ſhort, in a Depth of 25 or 30 Feet of Earth, it is eaſy to ſpring the ſame Surface next the Covert-Way 6 or 7 times; which is, doubtleſs, more than ſufficient to repel the moſt obſtinate Enemy.

All theſe Mines ſhould be ſo ranged as not to damage the Parapet of the Covert-Way: Thus it will always remain in a Condition to be taken as often as the Lodgment is demoliſh'd. During this Time, the Saps, Communications, and Parallels by which the Enemy maintains his Lodgment on the Covert-Way, muſt by no Means be ſpared. Beſides, there ſhould be continually ſome Fourneau a playing, merely for this Purpoſe, Namely, to blow-up thoſe Works, which the Enemy look upon as the moſt complete.

It muſt here be remarked, that if the Depth of Earth admits of blowing-up the Surface next the Covert-Way 6 or 7 Times, it is eaſy, on a Terre-plein of the ſame Depth, to range the Fourneaus in ſuch a Manner, as to blow-up the ſame Places 20 Times throughout the whole Glacis, or Country; becauſe they are not confined to one Side only, as when they are near the Palliſades.

If the Countermines ſo far anſwer as to render the Enemy incapable of making a Breach with his Cannon, and he nevertheleſs obſtinately perſiſts, that he ſhall ſucceed in his Enterpriſe, what are the Meaſures he is to take? Muſt he have Recourſe to Eſcalade? This Scheme is whimſical, and that from which a Garriſon ſkill'd in Defence has little to fear.

I ſhall however ſpeak to it, becauſe, I happened to be in a Place *, where the Garriſon, brave as it was, having done all that could be

expected,

---

* It was at *Landau*, in 1704. If Mr. *de Valliere* had been credited, this Place would have made a very different Defence from what it did. They would there have ſeen the Uſe of Tower-Baſtions, from which, the Beſieged did not think proper to reap any Advantage. Here follow, what Mr. *de Folard* relates on this Occaſion, in the 219th Page of the fifth Volume of his Commentary on *Polybius*.

" During the Siege of *Landau*, by the King of the " *Romans*, in 1704; the obſtinate Defence made by " Mr. *de Laubanie* obſtructed the Beſiegers Meaſures, " though they had made a Breach in the Body of the Place: " For, as the Baſtions of this important Fortreſs were cut " at their Gorges by Tower-Baſtions, the Breach, wide and " practicable as it might be, did not appear to me much to " moleſt the Garriſon. The Reaſon is, that the Ditches " being dry, thoſe of the Town (that is, thoſe which de" fended it) had this admirable Advantage, that they could " convey Water into them whenever they pleaſed, " which was an inſurmountable Obſtacle to any Threats " occaſioned by the Breaches, even though the Outworks " were taken, which cannot but be abundantly clear. " The Enemies, whether as an Artifice, or whether as " they had really a Deſign to give the Aſſault and Eſcalade " together, which would have been a very imprudent " Step, becauſe the Ditch might inſtantly be laid under " Water; the Enemies, I ſay, threw Scaling-Ladders " into the Trenches, which alarmed the Garriſon, who " were extremely weakened, and incapable to line the " Ramparts: Becauſe they did not know but that this " Eſcalade was deſigned to affect every Place, where it " might be poſſible to fix themſelves. Wherefore, in this " Dilemma, it was unanimouſly reſolved to open the " Sluice, and let-in the Water. Mr. *de Valliere*, an ex" perienced Officer, now Field-Marſhal, (and ſince the

" Printing

expected, were at laſt in fear of an Eſcalade: On which Suſpicion, they determined after two Days Debate, imprudently enough, to let the Water into their Ditches. But to return to the Enemy's Miner: This Miner has but two Ways of arriving at the Body of the Place, or the attacked Work. The one is, to paſs the Covert-Way under the Ditch; a tedious Undertaking, and wherein he will certainly be obſtructed: The other, to overturn the Counterſcarp, or make the Deſcent of the Ditch, in order to advance under Covert of an Epaulment. In the Execution of both theſe Enterprizes, they have it farther in their Power to diſtreſs him ſo effectually, as that he muſt be obliged to retire. But ſuppoſing he ſhould arrive at the Body of the Work; a principal Gallery,

---

" Printing of *Polybius*, Lieutenant-General) who commanded the Miners, was of a different Opinion; and " his Advice certainly was the beſt, though then oppoſed " by a great Majority. Mr. *de Laubanie* was rendered " incapable of judging for himſelf on either Side; for a " Shell, unfortunately falling near him a few Days before, had raiſed ſuch a Quantity of Earth as intirely " deprived this gallant Officer of his Sight. In this Condition he judged it moſt prudent to take Part with the " Majority; whereupon the Ditches were fill'd, and the " Enemy completely obliged in their Wiſhes. The reſult " demonſtrated, that Mr. *de Valliere*'s Judgment was infinitely ſuperior to the reſt; for the Place ſurrender'd in " a few Days."

with its Liſtners placed behind the Scarp of the Ditch, will render it impoſſible for him to ſucceed.

As to the preſent Practice, the Enemy's Scheme for arriving at the Covert-Way, is by covert Saps, or to expreſs myſelf more properly, by ſubterraneous Galleries; leaving only a Foot, or half a Foot, of Earth over Head; after which, they have nothing to do, but to throw down this Earth, and their Lodgments appear in a manner finiſhed. But in this Caſe, nothing is eaſier than to prevent the Progreſs of ſuch Works, and oblige them to purſue other Meaſures, if they chooſe them.

SINCE we ſee, even by the general Idea of it here given, what that Annoyance is, which Countermines are capable of producing; we have only to add to their Uſe the good Conduct of the Garriſon; who, beſides contributing by every other Method in their Power to the total Deſtruction of the Enemy, will think themſelves obliged, both from Experience and Duty, to be particularly careful in making the beſt Improvement of thoſe various Diſorders, which, the Enemy, may at any Time be thrown-into, on the ſpringing theſe Mines: I ſay, we need only take with us the preſent View of this Subject, and we ſhall readily confeſs, that theſe Countermines are

certainly

certainly the beſt, if not the only Manner of Defence, from which ſuch extraordinary Advantages are likely to accrue.

However, ſince we have not, as yet, either ſeen, or heard of, a Defence of this Nature; what I have now ſuggeſted in favour of the Uſe of Countermines, may, perhaps, be cenſured, as Matter of mere Imagination. But this is ſo far from being the Caſe, that I can aſſure the Reader, I have here advanced nothing, but what is founded on repeated Experiments. The Thing ſtands ſupported by Fact; and I aſſert not only its Poſſibility, but likewiſe the Eaſe attending its Execution.

I have never ſeen this Sort of Mines conſtructed with that Art they certainly require: Nor have I ſeen, in the various countermined Attacks where I have been, that the Enemy have reaped all the Advantage their Countermines afforded. For, whatever their Conſtruction be, there are always certain Advantages which ought to be made of them: But, the Knowledge of theſe Advantages wholly depends on Mechanics, aſſiſted by a certain geometrical Cunning, (if I may be allowed the Term) for which a peculiar Happineſs of Genius is required.

Permit me to ſay, that 15 or 20 Miners, as the Cuſtom generally is, detached againſt a beſieged Place, are by no Means ſufficient. For the utmoſt they can do, is to range a few Fourneaus, here and there, under the Glacis; which will, in a meaſure, it is true, intimidate the Enemy: But then the Annoyance, received from them, is quite trifling; nor does the ſmall Delay thus occaſioned, anſwer the Trouble expended. Beſides, for want of Communications, they are obliged to charge theſe Fourneaus upon the Enemy's Approach to the Covert-Way, which cannot but be a great Detriment. I have, likewiſe, farther to add, in reſpect to the Plan, on which Countermines have been hitherto conſtructed: That when the Number of theſe Miners is greater than that mentioned above, it muſt of Neceſſity happen, that as both the Beſiegers and the Beſieged will begin their reſpective Works, pretty near at the ſame Time, the Places themſelves may be frequently ſo ſituated as to give the Town no great Hopes of Relief from theſe Countermines.

WHEREFORE, to conſtruct Countermines in the Manner I propoſe, requires both Time and Expence. Not that either of them will be ſo great, as may poſſibly, be imagined. Three or four Months, will be ſufficient to furniſh a Place completely with Countermines, Provided no Rock intercepts: Nor ſo only, but likewiſe, to put ourſelves in Poſſeſſion of the Country for 60 or 70 Toiſes beyond the Palliſades, provided a proper Number of Workmen can be ſecured.

As to the Expence, I look upon it as trifling, in compariſon of the Millions laid out in building the Towns themſelves; this prodigious Expence, at the ſame Time, making it highly requiſite to uſe all poſſible Means for their Preſervation.

WHAT I have then to ſay, is, that for the Front of a Polygon of 200 Toiſes, I reckon 2000 Toiſes for the Galleries: Which for Materials and Workmanſhip together, may amount to about 35,000 Livres; beſides a Deſtination of 100,000 lb. of Powder for this Service.

HOWEVER, there is one Thing, to be obſerved, in carrying on theſe Works, which is, to be expeditious, and to countermine all the different Parts of a Fortification at the ſame Time; otherwiſe, you will endanger the Loſs of one Front, while you are ſecuring another: Beſides, that this will inform the Enemy of your Condition, which he always diſcovers but too ſoon.

THE SCIENCE of Countermines has a Superiority over that of Fortification. This latter is partly arbitrary: But the Situation and Conſtruction of Countermines are to be determined by three principal Things. Namely, firſt, by the Syſtem on which the Place itſelf is fortified. Secondly, by the different Dimenſions of the Solids of the contiguous Soils. And thirdly, by the Nature of the Soils themſelves. Another Advantage here, not leſs conſiderable than the former, is, that the Poſition of theſe Mines may be ſo diverſified, that it ſhall be impoſſible for the moſt ſagacious Enemy to gain any Intelligence.

THOSE GALLERIES, which are cloſed in Wood, are not only eaſier of Defence, but likewiſe more commodious for guarding againſt certain Accidents, than ſuch as are walled-up: But as we are obliged to line theſe Works with Maſonry to render them more durable; it is proper, in order to prevent theſe ſame Accidents, that the Top of the Galleries, that is to ſay, the interior Roof, be quite flat, and not arch'd as is generally practiſed.

FOR ſuch Objections as may be raiſed againſt the Method here propoſed for the Conſtruction of Countermines, I flatter myſelf, I ſhall find it no difficult Taſk to refute them. Now the chief Objection, I believe, is, the Difficulty of working in the Galleries, and of digging the Earth, when Powder has been often burnt in the Parts adjoining. It muſt, indeed, be confeſſed, that the nitrous and ſulphureous Vapours of the Powder, mixed with thoſe which are ſubterraneous, diffuſe ſuch a foggy and intolerable Stench in the Galleries, and in the Earth, that the Miners cannot poſſibly ſtand it. It often throws them into a Swoon, and kills them, if Care be not immediately taken to carry them off: But yet, in the Conſtruction of Galleries, ſuch Precautions are to be uſed as may effectually purify them, and give due Circulation to the Air, which cannot but prevent the Inconvenience complained-of.

I WISH, for the Public Good, that what I have now propoſed, were duly conſidered. I would even venture to affirm, that they would give it the proper Attention, had they but once experienced the extenſive Uſe of theſe Countermines †.

Expla-

---

† IT is greatly to be wiſh'd, that Mr. *de Valliere*'s Sentiments on Countermines, were conſidered with that Attention they deſerve. The great Things he performed in ſeveral Sieges, demonſtrates, what he could have done, in a Place countermined according to his own Method. It will be only when this takes Place, that, to uſe the Expreſſion of Mr. *de Folard*, we may hope to render a Siege, eternal. *A Man*, ſays this Author with the Genius of the famous *Valliere*, *commanding in a Place*, *ſuch as the Citadel of* Tournay, Conde, Landau, *or any other Town remarkable for Defences of this Kind*, *would keep the greateſt Armies at Bay*, and deſtroy an infinite Number of Men. It

Explanation of the Figures, and Diſpoſition of the Fourneaus.

IN order to obſerve the neceſſary Exactneſs required in the Conſtruction of Mines, it is proper we ſhould know the Figure of the Excavation formed by a Mine, when it is ſprang.

DEFINI-

It is certain, we want nothing but the true Art of Mining to put a Place in ſuch a Condition, as ſhall enable it to make a long and vigorous Reſiſtance. *Had Mr.* de Valliere *been at the Siege of* Tournay, ſays the Author now quoted, *two Years Proviſions would never have anſwered the Neceſſities of the Beſieged, nor would the Beſiegers have ever had it in their Power to have taken the Place, or, indeed, to have made one ſucceſsful Advance towards it.*

WE now abſolutely uſe ſo large a Train of Artillery in Sieges, that the ſtrongeſt Parapets, and Ramparts, are very ſoon demoliſhed. The great Number of Outworks ſerves only to retard a little the taking of a Place, and this Advantage is very dearly earned. For, in a Town of any Conſequence, it is neceſſary, that there be the Complement of an Army, in order to ſupport and defend it with any Succeſs: In conſequence of which, there muſt be likewiſe a prodigious Conſumption of all Kinds of Ammunition.

THE END and Deſign of Fortification, is, to lodge a ſmall Body of Troops in a Place, in ſuch a Manner, as may enable them, if attacked, to reſiſt a much ſuperior Force, not only to the beſt Advantage, but alſo for the greateſt Length of Time. It's Situation therefore is to make up for the Deficiency of Numbers; but if we muſt be obliged to have Armies for the Defence of Places, it is plain, their Fortification is defective in its own Nature.

WHERE-

DEFINITIONS.

THE Excavation or Aperture formed by the ſpringing of a Mine, is a *Parabolic Conoid*, or, which is the ſame, a *Paraboloid.*

THE Term given it in War is *Entonnoir.*

(FIG. I.) SOME have imagined that this *Entonnoir* was the Fruſtum of a Cone *AOZD*,

---

WHEREFORE the Science of Mines, by which we are enabled to defend them with a ſmall Body of Men, is certainly the true Science of Fortification, and that which beſt anſwers this noble Deſign. For, with a Garriſon ſufficient to guard the ſeveral Poſts, and a Company of 50, or 60 Miners, the Approaches to a Place become formidable; the Enemy is a long Time kept at a Diſtance, and his farther Advances rendered impracticable, as his Works will be continually demoliſh'd, and his Batteries infallibly blown-up; a Taſk which may be often repeated, provided the Fourneaus are diſpoſed on the Plan laid down by Mr. *de Valliere* in the Sequel of this Diſſertation. There is a much ſmaller Number of Men required, to guard the ſubterraneous Works of a Place, than thoſe, which are uppermoſt; and the Beſieger, who takes due Care to provide himſelf with ſubterraneous Galleries for ſecuring that Part which is below him, will alſo, by this Practice, find out the Means of becoming Maſter of that Part which is above him. The Concluſion then from the whole of this is: That the Art of Mining is undoubtedly of the utmoſt Importance, and that the Fate of moſt Towns, at preſent, depends on a thorough Skill in this Science. For, while they continue to uſe ſuch a numerous Artillery in the Attack of Places, there is nothing but Mines, which we can effectually employ in their Defence.

whereof the Diameter *O Z* of the leſſer Baſe, was equal to the Semi-diameter *A D* of the greater Baſe.

(FIG. II.) SOME chooſe rather to give it the Figure of a plain rectangular Cone *A F D*.

(FIG. I, II, and III.) However, it muſt be obſerved, that in theſe two Cones, as well as in the *Conoid A H O B I S D*, the Axis or Line *F R* drawn from the Center of the Fourneau *F* to the point *R* in the Plane of the Baſe of the *Entonnoir*, is always equal to the Semi-diameter of this Baſe.

This Line *F R*, I term *the Line of leaſt Reſiſtance.*

BY carefully examining this *Entonnoir* form'd by the Effect of a Fourneau, we eaſily perceive that its Sides are curve * and not right Lines, as appears by the 1ſt, and 2d, Figures.

I SHALL

---

* IT evidently appears, that the Sides of the Entonnoirs ought rather to be curve Lines, than right ones; and that as it ſhould ſeem for the following Reaſon.

THE POWDER, in taking Fire, acts at once, equally on all Sides of the Fourneau; and as the Surface of Earth, which is immediately over it, makes leſs Reſiſtance than the

I SHALL now give ſome Account of the Meaſures I took for finding the Dimenſions of this Entonnoir.

REMARKS.

BUT I muſt firſt obſerve, that the Method I am going to treat of, will only ſerve when the Fourneau is to be ſprang in Soils, where there appears no Traces of Mines having been ſprang in

---

the other Sides, that, of courſe, is blown-up firſt. Now, it cannot be blown-up without diminiſhing the Action of the Powder round about it; and conſequently the firſt Effort, whoſe Direction was in a right Line, is not equally continued. From whence it follows, that the Aperture is not made according to the firſt Radii of the Inflammation; and that, by this Means, the Action of the Powder decreaſing, it cannot but take different Directions, and therefore form the Sides of the Excavation in curve Lines. As this Curvature is very ſmall, they have conſidered it, in Practice, as a right Line; juſt as they do when they meaſure the Aperture of a Mine, on Suppoſition of its being the Fruſtum of a Cone.

As this Way of reaſoning may ſeem to countenance an antient Opinion: Namely, that a Mine overcharged with Powder, produces nothing, but an Hole like a Pit, it is proper, I ſhould here endeavour to demonſtrate the contrary.

WE have juſt now obſerv'd, that the Powder in taking Fire, acts equally on all Sides of the Fourneau; it's Effort, however, on the Parts below the Chamber, can act only by a light Impulſe, in Conſequence of which, it is reflected back towards the Surface of the Earth: Then as the whole Preſſure againſt this Surface is greater, and therefore capable of forming a larger Aperture; it, conſequently, acts with more Extenſion towards the Surface, and in them before, and that has not been plowed, mild and homogeneous.

THE RUBBISH will not admit of our taking theſe Meaſures in ſuch Soils, as the Miners term *Looſe*.

IT muſt alſo be obſerved, that the Heterogeneity of Rock and Maſonry, very often

---

and cauſes a more violent Concuſſion in the ſeveral Parts, with which it communicates: A Concuſſion, which is proportionably more violent and farther extended, as the Powder in the Fourneau exceeds in Quantity. The Surface of the Earth, which is moſt contiguous to the Fourneau, firſt yields to the Force of the Powder; but, at the ſame Time that it yields, the Powder does not ceaſe acting on the other Sides of the Fourneau; it continues to compreſs, protrude, and ſeparate the Parts of the Fourneau towards the Surface; only, that, in this reiterated Impulſe, it rather acts with leſs Force: Its proper Action therefore, is not, as ſuppoſed to produce a Pit, but merely to blow-up the Earth about the Line of leaſt Reſiſtance.

IF it were with the Powder in the Chamber of a Mine, as it is with that confined in a Cannon, meaning that, in the former Caſe, it could only exert it's Force towards the Top of the Fourneau; as it is certain, that it can, in the latter, only act towards the Mouth of the Cannon; the Conſequence then, indeed, would be, that it muſt of neceſſity produce a Pit for the Excavation of the Mine: But, for as much as the Parts contiguous to the Fourneau, cannot but receive conſiderable Impreſſions from the Action of the Powder; it is not only certain, that theſe Parts muſt needs ſuffer a remarkable Shock, while the Powder is making it's Progreſs to the Surface; but alſo, that this Shock of the Neighbouring Parts muſt remain during the continued Action of the Powder, which firſt put them into Motion, and therefore of Conſequence throw-out the Earth, thus agitated, in a circular Form round the Line of leaſt Reſiſtance.

cauſes the Powder to produce irregular Effects.

EXPERIMENTS.

I MEASURED a great many of theſe Entonnoirs with the utmoſt Circumſpection poſſible. I had ſeveral of them cleared of the Earth, which fell in when it was ſprang. I likewiſe had ſome of the Pits, *KMLI*, dug deeper. After ſeveral repeated Searches, I found certain Lines, which conſtantly preſerved the ſame Relation in each Entonnoir, however their Depths might vary.

(FIG. III.) THESE are the Lines: The Center of the Fourneau is *F*; the Line of leaſt Reſiſtance is *FR*. From the right-angled Iſoſceles Triangle *ARF*, I took the Hypotheneuſe *AF*, and carried it from *B* to *T*. I found *RT* equal to *FB*. *B* is the Bottom of the Entonnoir, where the Earth is found black and baked by the Flame of the Powder. *RT*, being equal to *FB*, made me think that *F* might be the Focus of a Parabola, * whoſe Vertex was *B*, *RA* an Ordinate, and *RT* or *FB* $\frac{1}{4}$ of the Parameter.

---

* See the Properties of the Parabola, in Mr. *Belidor's* Courſe of Mathematics, Page 137, &c.

I TOOK indefinitely *B V*, from which I ſubtracted $VE = FB$, drew the Ordinate *E H*, and found $FH = BV$. I found $FO = 2\ FB$.

I LIKEWISE found $FK = 2FB - FX$. Theſe Equalities of Lines are the Properties of the Parabola. I found the ſame Thing, when I made $BC = BF$, in digging the Pit *K M L I* deeper, and took the Diſtances of the Ordinates on the Axis from the Point *C*. This Point *C* is the Interſection of the Axis produced, and the Directrix *L M*. *C F* is equal to half the Parameter.

FIG. IX. XI. *and* XIII. WE may therefore conclude that the Entonnoir is a Paraboloid, whoſe Focus is the Center of the Fourneau *F*, and of which *F R*, Part of the Axis comprized between the Focus and Plane of its Baſe, which I term the Line of Leaſt Reſiſtance, is always equal to the Semidiameter of the Baſe *A D*, or equal to the Ordinate *R A*.

OBSERVATION.

FIG. IV. V. VI. VII. VIII. SINCE the Line of leaſt Reſiſtance *F R* is always a Perpendicular on the exterior Plane *A D*, neareſt the Fourneau, the Poſition of the Conoid, after ſpringing the Mine, is determined by the Situation of this exterior Plane, whether it be horizontal, vertical, or inclined; conſequently therefore, the Poſition of the Fourneau depends on this exterior Plane *A D*.

I JUST now obſerved, that the Poſition of the Fourneau depends on the Situation of the neareſt exterior Plane, which is true; but to expreſs myſelf without Ambiguity, I ought to ſay, the Poſition of the Center of the Fourneau. The Place of this Focus depends likewiſe on the Maſs to be blown-up. This Maſs alſo determines the Charge, and conſequently the Size of the Fourneau.

THERE is a Method, though very ſimple, yet hitherto unthought of, for defending the Approaches and Covert-way of a Place by Mines; for managing the Ground to the beſt Advantage, and moleſting the Aſſailants as much as poſſible; and, in all Probability, for repelling them by the ſaid Mines.

THE WHOLE Art conſiſts in ſuppoſing a Plane in the Earth, which cuts the Plane of the Glacis under an Angle of 45 Degrees.

DEFINITIONS.

(FIG. IX.) THIS ſuppoſed Plane, I term *Plane of the Fourneau*, or *Plane of the Foci*; becauſe it is on this Plane that the Focus or

Center of each Fourneau ought to be placed. It is marked here by the Lines *A A*, *B B*, with the Fourneaus. *C* repreſents the firſt Fourneaus, *E* the ſecond, *B* the third: The Line *A A* is the Directrix.

(FIG. X.) THE PLANE of the Glacis is repreſented by the Lines *P P*, *X X*. *P P* is the *Ridge* of the Covert-way, *D D* the Directrix. The Figures 2, 3, 4, repreſent, on the Plane of the Glacis, the correſponding Perpendiculars of the Foci; or, if you pleaſe, the Extremities of the Lines of leaſt Reſiſtance. The little Circles repreſent the Aperture or Effect of the firſt eight Fourneaus; the mean, the Effect of the four ſecond; and the great, the Effect of the two third Fourneaus.

THE COMMON Section of the Plane of the Foci, with the Plane of the Glacis, gives the Directrix *A A* or *D D*.

PROFILS.

FIG. XI. Horizontal or level Glacis.

FIG. XII. GLACIS, whoſe Slope inclines or deſcends towards the Field.

FIG. XIII. GLACIS *à revers*, whoſe Slope inclines or deſcends towards the Place.

(FIG. X.) THE LINE *G H* is the Section of the Plane *P P*, *X X*.

THE LINE *F L* is the Section of the Plane *A A*, *B B* (Fig. IX.) Thus *F L* agrees with *A B*. The Point *G* agrees with the Line *P P*. The principal Point *F* agrees with the Directrix *A A*, or *D D*. The Point *O* with the Foci *C*. The Point *M* with the Foci *E*. *L* with the Foci *B*; and the Points *Z*, *X*, *Y*, with the Lines 2, 3, and 4.

TO PREVENT the Parapet of the Covert-way being damaged by the Effect of the Fourneaus, Care muſt be taken to place the principal Point *F*, or the Directrices *A A*, *D D*, at the Diſtance *G*, or *P P*, from the Parapet, as at that of 3, 4, 5, or 6 Feet. In this Example *F* is 4 Feet from *G*.

CONSTRUCTION.

(FIG. XI. XII. XIII.) IF CONVENIENCY determines me to place the firſt Story of Fourneaus ten Feet under the Glacis, I make *F Z* equal to ten Feet. From the Point *Z*, I drop the Perpendicular *Z O* on *F Z*, which meeting the Diagonal *F L* at *O*, gives the Focus *O*. *O Z* is the Line of leaſt Reſiſtance, and by Conſtruction is equal to ten Feet.

On the Line *A N* (Fig. IX.) I take *A I* equal *F O*. Thro' the Point *I*, I draw the Line *C C* parallel to *A A*. On the Line *C C* I mark the firſt Fourneaus *C*, each at ten Feet Diſtance, which is conſequently equal to their Line of leaſt Reſiſtance.

For the Second Fourneaus.

On the Diſtance of the two contiguous Foci *C C* (Fig. IX.) as a Baſe, I deſcribe the Iſoſceles Triangle *C E C*, and make the Sides *C E*, *C E*, each equal the Line of leaſt Reſiſtance *O Z* of the Fourneau *O* or *C*. Thro' the Vertex *E* of this Triangle I draw the Line *E E* parallel to *C C* or *A A*; on this Line *E E*, I mark the ſecond Fourneaus *E*, in ſuch a Manner, that each *E* is oppoſite the Center of the Diſtance between the two contiguous *C*'s, two by two alternately. On the Line *A N*, I take the Diſtance *I E*, and carry it to the Profil of *O* in *M*, ſo that *M* may be the Center of the ſecond Fourneau. I draw *M X* parallel to *O Z*, which gives *M X* for the Line of leaſt Reſiſtance of the ſecond Foci *M*.

For the Third Fourneaus.

On the Diſtance between the two contiguous Foci *E E* as a Baſe, I deſcribe an Iſoſceles Triangle *E B E*, whoſe Sides *E B*, *E B*, I make each equal the Line of leaſt Reſiſtance *M X* of the ſecond Focus *M* or *E*, on which I mark the third Focus *B*, in the ſame Order with reſpect to the Second, as I obſerved between the ſecond and firſt. On the Line *A N* I take the Diſtance *E N*, and carry it to the Profil *M* in *L*, to make the Focus *L*, Center of the third Fourneau. I draw *L Y* parallel to *M X*, and I get *L Y* for the Line of leaſt Reſiſtance of third Foci *L*.

By CALCULATION.

The firſt Fourneaus.

(*Fig.* 9, 11, 12, and 13.) The Line FZ or $ZO = 10$ Feet $= a$. Therefore, FO or $AI = \sqrt{2aa} = \overset{F}{14}.\ \overset{I}{1}.\ \overset{T}{4}.$ *

The ſecond Fourneaus.

In the Iſoſceles Triangle CEC, $CE = a$ by Conſtruction, the ſame as CC: Therefore $IC = \frac{a}{2}$. And $IE = OM =$ † $\sqrt{a^2 - \frac{1}{4}a^2} = \overset{F}{8}.\ \overset{I}{6}.\ \overset{T}{6}.$ Let this Value be ſuppoſed $= b$.

---

* The Triangle FZO being right angled $FO^2 = \overline{FZ + ZO}\rceil^{2}$. Theſe Sides are each 10 Feet, whoſe Square is 100; thence the Square of $FO = 200$; and conſequently, $FO = \sqrt{200} = \overset{F}{14}.\ \overset{I}{1}.\ \overset{T}{4}$

† In the right angled Triangle EIC, $IE^2 = \overline{EC - IC}\rceil^{2}$. Now $EC = \overset{F}{10}$, $IC = \overset{F}{5}$, therefore $IE^2 = \overline{10 \times 10} = 100 - \overline{5 \times 5} = 25 = 75$. Conſequently its Square Root which is the Value of $IE = \sqrt{75} = \overset{F}{8}.\ \overset{I}{6}.\ \overset{T}{6}.$

We ſhall have $\sqrt{\frac{b^2}{2}} = ZX = MX - a =$
$\overset{F}{6}.\ \overset{I}{1}.\ \overset{T}{6}.$

The third Fourneaus.

In the Iſoſceles Triangle EBE, let $EB = MX = c$. Now $EE = 2a$, therefore EN on the Line AN or ML * $= \sqrt{c^2 - a^2} =$ 12.

Again, ſince the Line OM (Fig. 11, 12, and 13) has been taken equal to IE, it follows, that it is likewiſe $= \sqrt{75}$. If from the Point O a Perpendicular be ſuppoſed drawn to MX, it will form a right angled Triangle with OM, and that Part of the Line MX towards the Point M, and be equal to ZX. This Triangle will be Iſoſceles, becauſe it is ſimilar to the Triangle FZO: For this Reaſon, the Square of the Hypothenuſe OM will be double the Square of either of the other Sides. Now, $OM^2 = 75$, therefore the Square Root of each Side of this Triangle will be $\frac{75}{2}$; whoſe Square Root, $\frac{\sqrt{75}}{2}$, will be the Value of each of the ſaid Sides, and conſequently of ZX. This Root is found to be $\overset{F}{6}.\ \overset{I}{1}.\ \overset{T}{6}.$ becauſe of the ſimilar right angled Triangles FZO, FXM, $FX = XM$; but $FX = \overline{FZ + ZX}$, which is, $\overline{10 + \frac{\sqrt{75}}{2}}$, or $\overset{F}{16}.\ \overset{I}{1}.\ \overset{T}{6}$; conſequently $MX = \overset{F}{16}.\ \overset{I}{1}.\ \overset{T}{6}.$

* It is evident, that EN is equal to the Perpendicular drawn from the Point B to the Baſe EE of the Triangle EBE,

$\overset{F}{12}.\ \overset{I}{7}.\ \overset{T}{2}.$ Let this Value be $= d.$ we ſhall have $\sqrt{\frac{d^2}{2}} = XY = \overline{LY - c} = \overset{F}{9}.$

We ſee therefore, that when the Glacis can be digged twenty-five Feet one Inch perpendicularly, the firſt Fourneaus being ten Feet deep; there is room for three Stories of Fourneaus, unleſs the firſt in ſpringing damage the

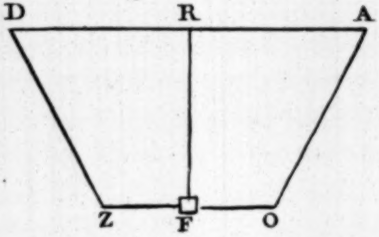
---

EBE, and that conſequently $EN^2 = EB^2 - \frac{EE^2}{2}$, which half is $= a$, or 10, that is, in naming EB or MX, c the Square of EN or MX, will be $= c^2 - a^2$. Therefore, EN or $MX = \sqrt{c^2 - a^2}$. Now, $c^2 = \overline{\overset{F}{16}.\ \overset{I}{1}.\ \overset{T}{6}. \times \overset{F}{16}.\ \overset{I}{1}.\ \overset{T}{6}.} = 262$ Feet nearly; $a^2 = \overline{10 \times 10} = 100$; therefore $\sqrt{c^2 - a^2} = \sqrt{262 - 100} = \sqrt{162} = \overset{F}{12}.\ \overset{I}{7}.\ \overset{T}{2}$, this is alſo the Value of ML. By ſuppoſing, as in the preceding Note a Perpendicular drawn from the Point M on LY, it will be equal to XY, and its Value will be $= \frac{\sqrt{162}}{2} = \sqrt{81} = 9$: Now $FY = \overline{FZ + ZX + XY}$, that is, $= \overline{10 + 6.\ 1.\ 6. + 9}$, which added together gives $\overset{F}{25}.\ \overset{I}{1}.\ \overset{T}{6}$; therefore, LY which is equal to FY, is likewiſe equal to $\overset{F}{25}.\ \overset{I}{1}.\ \overset{T}{6}.$ Whence it appears that where they can dig this Depth of Earth, there may be placed three Stories of Fourneaus.

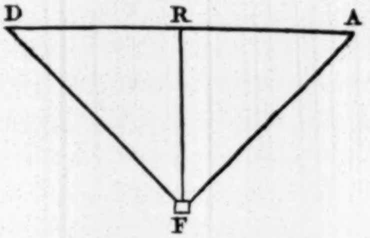
others. It is eaſy to place as many Stories of Fourneaus as the Depth of the Earth will admit of. By following the forementioned Conſtruction, we find that the Profil and Plane of the Foci reciprocally aſſiſt each other. The Profil determines certain Dimenſions of the Plane of the Foci, and the Plane of the Foci determines thoſe of the Profil.

THE LINE of leaſt Reſiſtance *O Z* of the firſt Fourneaus *C*, determines the Diſtance from *C* to *C*. It likewiſe determines the Diſtance between *C* and *E*. The Line of leaſt Reſiſtance of *M X* determines the Diſtance from *E* to *B*, and thus the Diſtance between the lower and upper Foci is always the Length of the Line of leaſt Reſiſtance of the Upper: But looſe Soils are ſometimes met with, and then the Line of leaſt Reſiſtance, for the Diſtance of the Fourneaus, muſt be lengthened. I never obſerved that this Increment exceeded one Third; that is, if the Line of leaſt Reſiſtance is twelve Feet long, the Diſtance of the Foci will be ſixteen Feet. Practice fully directs us in this Caſe; the Conſtruction for the reſt, is always the ſame.

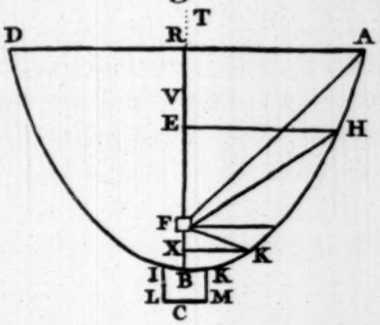
Fig. 1



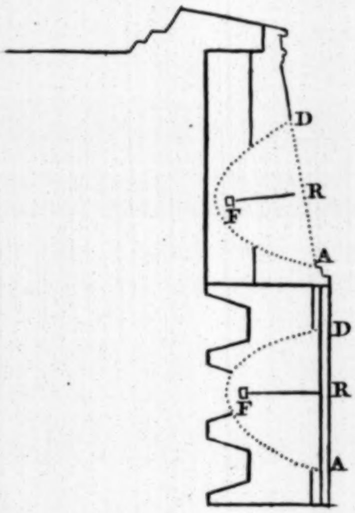
2



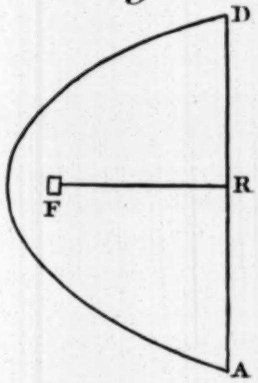
3



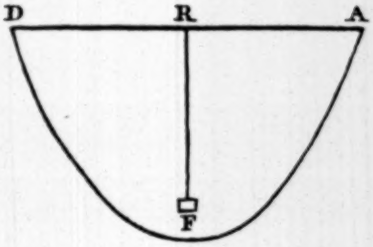
4



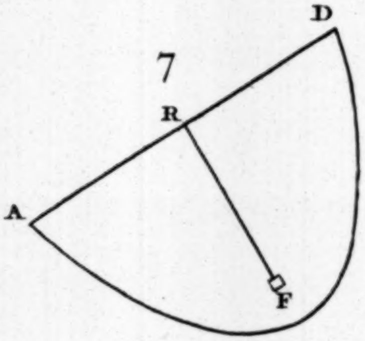
5



6



7



8

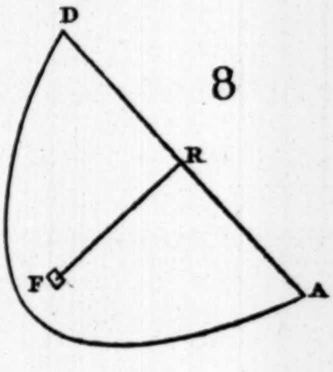
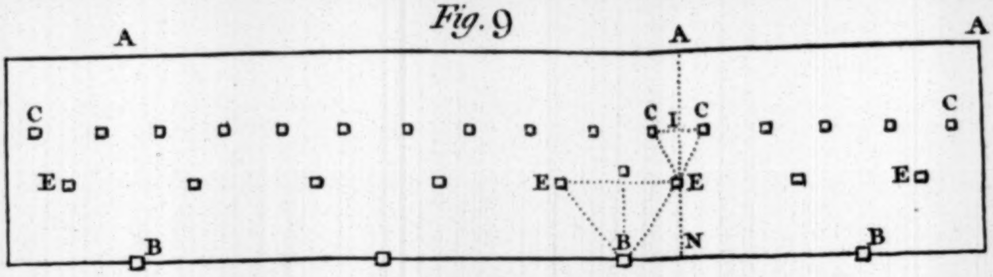
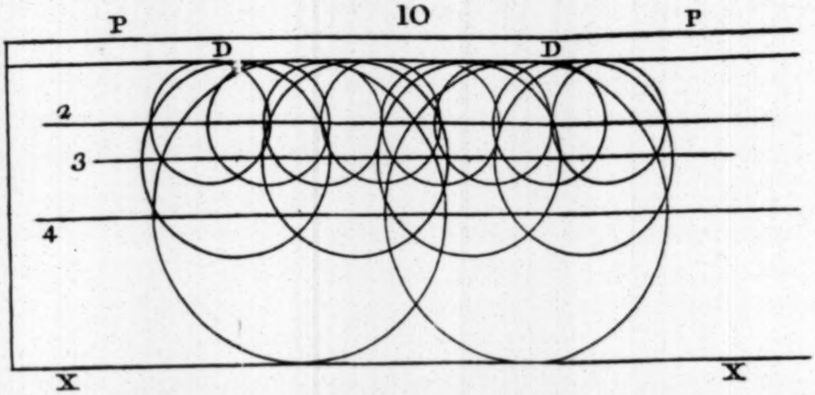


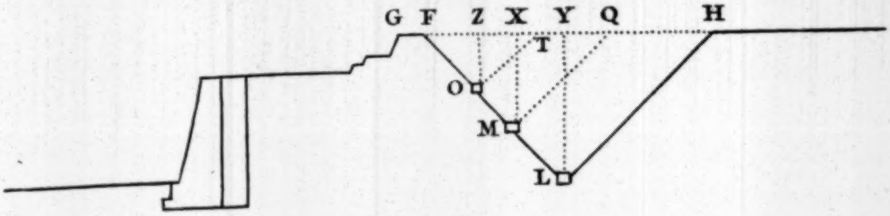
Fig. 9



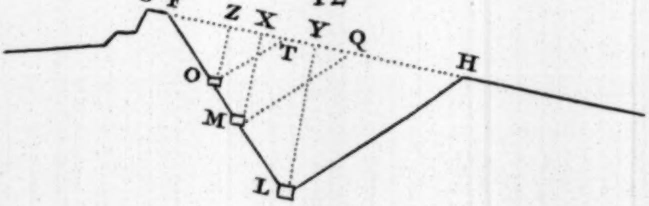
10



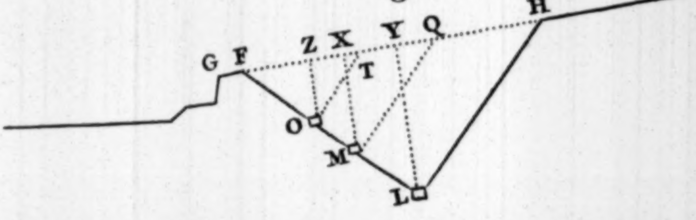
11



12



13



Mr. de VALLIERE'S TABLE *for the* CHARGES OF MINES.

Length of the Lines of leaſt Reſiſtance.	*Quantity of Powder Requiſite for the Charges.*		*Length of the Lines of leaſt Reſiſtance.*	*Quantity of Powder Requiſite for the Charges.*	
Feet	Pounds	Oz.	Feet	Pounds	Oz.
1	0	2	21	868	3
2	0	12	22	998	4
3	2	0	23	1140	10
4	6	0	24	1296	0
5	11	11	25	1558	9
6	20	4	26	1648	0
7	32	2	27	1815	4
8	48	0	28	2058	0
9	68	5	29	2286	7
10	93	12	30	2530	4
11	124	12	31	2762	4
12	162	0	32	3072	0
13	205	15	33	3369	1
14	257	4	34	3680	12
15	316	4	35	4019	8
16	384	0	36	4374	0
17	460	9	37	4748	11
18	546	12	38	5144	4
19	643	0	39	5561	2
20	750	0	40	6000	0

A New Method of making Experiments for finding the Quantity of Powder requiſite for the Charge of Mines.

AMONG the ſeveral Branches of War, there is not one, where Mathematics and Phyſics have a greater Share, than in that of the Science of Mines, were we diſpoſed to treat it with all that Train of Theory which we find annexed to it. Moſt of thoſe Engineers, who have hitherto had the Conduct of them, have made it to conſiſt chiefly in the acquiſition of ſuch a Portion of Knowledge, as might enable them to advance a Gallery to ſuch a certain Length, as might give them an Opportunity of placing the Fourneaus exactly under that Spot, which they intended to blow-up. Here then a ſmall Matter of Practice, together with the Uſe of a few Tables for the Charging of Mines, was quite ſufficient. And thus carrying their Views no farther than the common Manual Operations, they have not even once ſuſpected, that there were Rules, which might teach them to determine the different Forces of Gunpowder; and what is yet more, that there is alſo a particular Attention required for conducting both Galleries, and Branches with ſuch Advantage, as to render a Place not leſs formidable by theſe ſubterraneous Works, than it is capable of being made by any, the ſtrongeſt Fortifications. And in all probability, we had ſtill laboured under this ſame Prepoſſeſſion, had not Mr. *D'Valliere* ſhewn us, that to qualify an Engineer to conduct Mines, ſucceſsfully, there is an happy Art, which Geometry alone is capable of unfolding. It is therefore, wholly, on his Principles, that I am now going to explain, one of the moſt eſſential Parts of the Science of Mining.

THE USUAL Method of charging Mines, is, after having found the Quantity of Earth to be blown-up, to multiply it by the Quantity of Powder neceſſary to raiſe a Cubic Toiſe of this Soil: For Example, if it be a Soil where there appear no Traces of Mines having been ſprang there before, and they have Thoughts of employing ſixteen Pounds of Powder for each Toiſe; being deſirous of knowing, what Quantity of Powder is requiſite for a Mine whoſe Line of leaſt Reſiſtance is fifteen Feet, they multiply twenty-eight Cubic Toiſes, which is the Quantity correſponding to this Line, by Sixteen; the Product is 448 Pounds of Powder, for the Charge of the Mine.

IT is thus, that we have hitherto proceeded, to find the Charges of Mines: But when we come to conſider, that in the Effect of Mines, regard is to be had not only to the Weight of the Soils, but likewiſe to their Tenacity; we ſhall find, that for ſettling the exact Proportion of Powder, neceſſary for the Charge of two different Fourneaus, it will by no Means anſwer, to confine our Regard to the Quantity of Earth, belonging to each: What I mean is, that if we have eight Cubic Toiſes to raiſe in the one of them, and ſixteen Cubic Toiſes in the other, of the ſame Soil; the Charge of the two Fourneaus is, at no rate, to be determined by the Ratio of eight to ſixteen; becauſe, by this Method, the greater Fourneau will be over-charged, in Proportion, to the leſſer; as I ſhall preſently ſhew.

We know that ſimilar Solids are as the Cubes of their Axes: Therefore, if there are two Fourneaus to be ſprang, whoſe Lines of leaſt Reſiſtance are unequal, theſe Fourneaus having ſimilar Fruſtums of Cones to blow-up, we may ſay, that their Maſſes are in the Ratio of the Cubes of the Lines of leaſt Reſiſtance. But we know, likewiſe, that the Area's of ſimilar Solids are as the Squares of their Axes; and ſince the Tenacity of Soils with reſpect to the Effect of a Fourneau, exactly correſponds to the Area of the Solid to be blown-up; we muſt be ſenſible, that if, in the Effect of Mines, both the Weight and Tenacity of the Soils are to be conſidered, the Cubes and Squares of their Lines of leaſt Reſiſtance are the Things which muſt here determine. Now, ſince the Powder acts with greater Violence for looſening the Soil, than it does for blowing it up: It is plain I have good Reaſon to aſſert, that not only the Weight, but alſo the Tenacity of the Soil is to be conſidered. Again, if we reflect, that of ſeveral ſimilar and unequal Solids, the Area of the greater is proportionably leſs than that of the ſmaller; we ſhall find, as we may be allowed to expreſs the Tenacity of the Soils by the Area of the Solids, which the Powder is to raiſe, or by the Square of the Line of leaſt Reſiſtance, that there is, in Proportion, leſs Coheſion in thoſe Mines which have the greateſt Lines of leaſt Reſiſtance, than there is in thoſe, which have the ſmalleſt. For Inſtance, let us ſuppoſe two Fourneaus, the Line of leaſt Reſiſtance of the leſs to be ten Feet, and that of the greater Twenty, the Tenacity of the Soils will be as the Squares of ten and twenty, that is, as 100 is to 400; and their Weight, as the Cubes of ten and twenty, that is, as 1000 is to 8000. Which demonſtrates, that in theſe two Mines, whoſe Lines of leaſt Reſiſtance are double the one to the other, the Weight of the Soil of the greater is Octuple to that of the leſſer; while the Coheſion of the greater is only Quadruple to that of the leſſer: Wherefore, if we are only to have regard to the Quantity of Earth, in the charging of Mines; it would follow, that the greater Mines, would, in Proportion, be charged more than the leſs, and of courſe occaſion an unneceſſary Conſumption of Powder, which could not but prove of ill Conſequence by throwing the Rubbiſh of theſe Mines, on ſuch others, as have not been yet ſprung.

If we were now inclined to examine in what manner the Air is capable of bearing Part in the Effect of Mines, it would be neceſſary to conſider it's elaſtic Force, when it is dilated in a Fourneau; in what Ratio this Elaſticity increaſes in Proportion as the Powder takes Fire; what are the Alterations it is capable of receiving from the Reſiſtance of the Body it protrudes; and likewiſe to calculate the very Preſſure of the Atmoſphere, which correſponds to the Lines of leaſt Reſiſtance; demonſtrating that this Preſſure is as the Squares of the Lines of leaſt Reſiſtance, while the Preſſure of the Soils is as the Cubes of the ſame Lines. But as this would inſenſibly lead me into abſtracted Phyſics, which require the previous Knowledge of certain Principles, not ſo much as ſuppoſed in this Place; I ſhall content myſelf with ſuch Obſervations, as bear the greateſt reference to Geometry; that ſo nothing may be here advanced, which will not admit of ſtrict Calculation.

As a Regularity of Method in the Study of the Sciences, and the practical Application of Arts, is univerſally confeſſed to be the only Means of arriving at a ſuperior Degree of Knowledge; you have here, if I am not miſtaken, an eſtabliſhed Rule for computing the Force of Gunpowder in Mines; and which, if adhered to, cannot but enable us to determine the juſt Quantity, which ought to be allow'd, firſt for the Tenacity of the Soils, then for their Weight, and, laſtly, for both of them in conjunction.

HAVING ſeveral Mines, their Lines of leaſt Reſiſtance equal, and ſituated in a Homogeneous Soil, let three or four of them be charged with a moderate Quantity of Powder, juſt ſufficient to ſhake the Earth, ſo that the Circumference of a Circle may be traced on its Surface: And as it may happen, that the Engineers cannot directly determine the proper Quantity to produce this Effect, it is requiſite they be differently charged. Now, ſuppoſing all their Lines of leaſt Reſiſtance eight Feet, and that one of theſe Mines charged with fifty Pounds of Powder, produces the Circle required; that is, has traced a Circle the common Size of the Entonnoir, without having made a real Entonnoir; for I ſuppoſe the Earth within this

Circumference to be only a little raiſed: Now, if it be thus, the Quantity of Powder neceſſary to blow-up this Maſs muſt be meaſured by fifty Pounds of Powder: And as we have already ſhewn, that the Tenacity of Soils was as the Squares of their Lines of leaſt Reſiſtance; if afterwards, the Quantity of Powder proper to produce a ſimilar Effect in a Mine of the ſame Soil, and whoſe Line of leaſt Reſiſtance is twelve Feet, be required; you muſt ſay, as $64=\overline{8\times8}$: 50 lb. :: $144=\overline{12\times12}$: 112 lb. which is the Quantity requiſite to produce the Effect. And ſo of the reſt.

As Mines ſerve for ſeveral different Appointments, and there are ſome Caſes, where they cannot make too quick a Diſpatch of the Rubbiſh; I ſhall therefore have recourſe to ſome new Experiments, which are: That when there are three or four Mines, whoſe Lines of leaſt Reſiſtance are 8 Feet, I charge them all with a much greater Quantity of Powder than before, becauſe I would have large Entonnoirs well cleared: And as I am uncertain of the proper Quantity, I charge them differently. Let us then ſuppoſe that that Mine, which anſwers my Deſign, was charged with 70 lb. of Powder; I reckon this Charge quite ſufficient to overcome the Tenacity and Weight of Earth, whoſe Line of leaſt Reſiſtance is 8 Feet. Now, neglecting, at preſent, the Tenacity, which is found leſs in Proportion in a large Mine, than in a ſmall one; and having regard only to the Weight of the Earth; I recollect, that theſe Weights are as the Cubes of the Lines of leaſt Reſiſtance. That done, if I am aſked, what is the proper Charge for a Mine whoſe Line of leaſt Reſiſtance is 15 Feet, ſo as to produce an Effect analogous to the ſecond Experiment; that is, to make an Entonnoir; I ſay: If the Cube of a Line of leaſt Reſiſtance which is 8 Feet = 512, demands 70 lb; what will the Cube of a Line of leaſt Reſiſtance which is 15 Feet = 3375, require; and it produces 461: According to which Principle, if we pleaſe, we may proportion the leſſer Degree of Tenacity, which obtains in a greater Mine, when compared with one, that is ſmall; as I ſhall ſhew in the Sequel of this Eſſay.

In making ſimilar Experiments for all Kinds of Soils, I content myſelf with knowing, what Quantity of Powder is neceſſary for a Line of leaſt Reſiſtance, having firſt ſettled that Line of leaſt Reſiſtance for each different Soil reſpectively; becauſe I ſhall certainly have it in my Power, by this Step, to determine the Charge of Fourneaus in general, be their Lines of leaſt Reſiſtance, what they will: And this too by ſo general a Method, that it will be quite indifferent, whether the Aperture of a

Mine be a Paraboloid, the Fruſtum of an inverted Cone, or any other Solid; ſince, there is no occaſion to meaſure them, for finding the proper Charge of the Mines. What ſeems to me of greater Advantage, in the Caſe, is, that, ſince to all Appearance, theſe Solids vary their Figure, in Proportion to their different Tenacities, it in no Reſpect incommodes me, whether the Excavation of a Mine be different in Maſonry, from what it is in a Rock; in a Rock, from what it is in Gravel; or in Gravel, from what it is in ordinary Soils: It is enough, that I know, that theſe Solids are ſimilar in Soils of the ſame Conſiſtence; and that being ſimilar, they are, conſequently, as the Cubes of the Lines of leaſt Reſiſtance: And on this Principle I readily find the Charge of all Fourneaus at large, as may be demonſtrated by the Tables made Uſe of by Miners; where I perceive, that for a Line of leaſt Reſiſtance of 8 Feet in common Soils, 48 Pounds of Powder are required: If it be demanded how much is requiſite for a Line of leaſt Reſiſtance of 15 Feet, I ſay, if the Cube of 8 = 512, gives 48; what will the Cube of 15 = 3375, give; the Anſwer is 316 lb. for the Charge required, which correſponds to the Number 15 in the Table, as may be ſeen, in that by Marſhal *Valliere*. And we proceed in like Manner for the reſt: Which ſhews, that it is ſufficient to retain one

Term only, for finding all the Charges of Mines, whoſe Lines of leaſt Reſiſtance are different.

FROM what has been ſaid, may be deduced an eaſy Method to calculate Tables for the Charges of Fourneaus, without puzzling oneſelf with the exact Figure of the Solid to be raiſed: But then, theſe Tables might be in Danger of becoming like thoſe, we call Antient; where, the Perſons who calculated them, only took Notice of the Weight, without any regard to the Tenacity: And thus we ſhould fall into the ſame Fault; that is, we ſhould overcharge the great Mines, in Proportion to the leſs: We muſt therefore endeavour to point out a Method for avoiding this Error, and at the ſame Time, demonſtrate the Uſefulneſs of the preceding Experiments.

WE have ſuppoſed, that the Tenacity of a Mine, whoſe Line of leaſt Reſiſtance was 8 Feet, was meaſured by 50 Pounds of Powder; and that the Tenacity and Weight together of the ſame Line, were meaſured by 70 Pounds; which is the Charge requiſite to make a clear Entonnoir. Now, if what is ſuppoſed neceſſary for the Tenacity, be ſubtracted from the Charge, which includes both the Weight and Tenacity together, the Difference will be the Quantity neceſſary for the Weight alone: Thus, ſubtracting 50 from 70, there will remain 20 lb. of Powder for the Weight proportioned to a Line of leaſt Reſiſtance of 8 Feet. Again, if the proper Charge of a Mine, whoſe Line of leaſt Reſiſtance is 15 Feet, be required; in ſuch ſort, that this Charge ſhall be in exact Proportion to that of 8 Feet; let the Quantity requiſite for the Tenacity be firſt found, by ſaying: If the Square of a Line of leaſt Reſiſtance of 8 Feet = 64, demands 50 lb. for the Tenacity; how much will the Square of a Line of 15 feet = 225, require? the Anſwer is found to be 175 Pounds of Powder. Now, to find how much is neceſſary for the Weight, ſay: If the Cube of a Line of 8 Feet = 512, give 20 lb of Powder for the Weight; what will the Cube of 15 = 3375 give? the Anſwer is, 132: therefore, adding together the two Terms thus found, we have 307 Pounds of Powder for the Tenacity and Weight of a Line of 15 Feet. But we have ſeen above, where regard is had to the Weight only, that when a Mine, whoſe Line of leaſt Reſiſtance is 8 Feet, was charged with 70 lb of Powder; it required 461 lb, for a Mine whoſe Line was 15 Feet: In conſequence of which, that Charge appears to be much ſtronger than this we have juſt now found; ſince it exceeds it by 154 Pounds, that being the Overplus which is put into a Mine of 15 Feet, where it is not obſerved, that large Mines have proportionally leſs Tenacity than ſmall ones.

THE PRECEDING Experiments, appear to me of ſufficient Conſequence to deſerve a Trial, and an Exerciſe of this Kind is what Students ought to apply themſelves to, while in the Academy, and this not partially, but at large, becauſe the Soil found in one Neighbourhood may be very different from that in the next: By this Means, Tables, in the End, may be calculated for all Soils, whereas thoſe now extant, ſeem only to regard the ordinary Soils: And as theſe Tables have been made by different Perſons, the Tables of one Perſon are intirely different from thoſe of another; and what is ſtill more ſurprizing, is, that the greater Part of thoſe who uſe them, employ them promiſcuouſly both in the Attack and in the Defence of Towns, without making the proper Diſtinction in theſe Caſes: Notwithſtanding the Mines of the Beſiegers, and thoſe of the Beſieged, have a very different Object. For the Beſiegers Mines, ſo far as they reſpect the Covert-Way, and even the Breaches, cannot make too large Apertures, for forming ſpacious Lodgments, and making room for a large Body of Troops; whereas, thoſe of the Beſieged, are merely deſigned to throw down the Enemy's Works: Wherefore, if for blowing-up ſome Gabions with 8 or 10 Men, they make Entonnoirs ſufficient to lodge whole Companies of Grenadiers, they will find too late, that they have been taking a Step highly prejudicial to their own Safety. Nevertheleſs, there are ſome Inſtances, where it is neceſſary that the Mines of the Beſieged ſhould produce great Effects; but theſe are only when Batteries are to be blown-up: For, if theſe Batteries chance to be erected oppoſite the only Place, where it is poſſible to make a Breach; then indeed, the greater the Entonnoirs are, the longer Time conſequently will be required to fill them up, and repair the Damage ſuſtained: Beſides, theſe Entonnoirs will not ſerve for Lodgments, to the Enemy, ſince by the Time they could be converted to this Uſe, he will be found Maſter of the Covert-Way, and will want this very Place to rebuild his Battery.

Mr. Belidor adds, that having ſent this Memoir to the Court, Orders were given to try theſe Experiments. They have been accordingly tried, and the Reſult of them is expected in the Treatiſe of Mines, with which he has promiſed to oblige the World.

BRITISH MUSEUM

The END.